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Final Report

Eisenhower Consortium

PRESCRIBED BURNING IN PINE FORESTS OF THE BLACK HILLS

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FINAL REPORT

Eisenhower Consortium

Prescribed Burning in Pine Forests of the Black Hills

Cooperative Agreement No. 16-471-CA
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Chapter 1. Introduction

Purpose of Study

Prescribed fire planning and decision making require a complete definition of the conditions of weather and fuel moisture for a successful burn. An estimate of the frequency with which these particular conditions occur is also an aid in this planning process. The problem dealt with in this study was the ascertainment of the number of days suitable for prescribed burning of ponderosa pine forests in the Black Hills. This determination by necessity was preceded by an estimate of the weather and fuel conditions necessary to conduct a successful burning operation.

The specific objectives of the research were to:

1) Define candidate fuel types for prescribed burning in the Black Hills
2) Define the successful result of fire in each fuel type
3) Describe the weather and fuel conditions necessary for the successful result
4) Calculate the probability of occurrence of the necessary conditions
5) Describe the sensitivity of possible number of burning days to each prescription parameter.

Fire as a Management Tool

In the past, fire as a management tool has had limited use in the West. However, this is changing in response to the growing science and technology that is developing. Controlled burning in the Black Hills has been successfully demonstrated as a useful practice for maintaining high quality grasslands and to reduce dangerous accumulations of dead ground fuel (Gartner and Thompson, 1972). In Washington, Oregon, California, and several other western states, fire has long been used as a silvicultural tool in ponderosa pine. The most notable users of fire have been H. H. Biswell (1972) and Harold Weaver (1967) who have pioneered and practiced most of the burning in ponderosa pine. Natural fires can be successfully replaced by periodic prescribed fires, with a silvicultural benefit.

Prescribed fire is an increasingly important management tool for ponderosa pine in the Black Hills. Forest officers may eventually use fire in this area for a wide range of objectives. Some of the general uses of prescribed fire are to:

1) Reduce of timber harvest residues
2) Improve forage and browse production
3) Thin stagnated sapling stands
4) Reduce dead fuel and litter accumulations
5) Reduce established pine seedlings in grasslands or meadows.

The future of prescribed fire is promising. A burning program in the Black Hills might be similar to one used on some Indian land in the Southwest since 1948 (Biswell, et al., 1973; Kallander, 1969). Research there has shown that a 6-7 year burning cycle in ponderosa pine would provide maximum fire protection. The cost of prescribed burning is low when compared to the cost of wildfire suppression.

An expanded burning program would certainly require a more rigorous definition of burning conditions necessary to meet the management objectives of the area. A prescription might include the following elements:

1) Air temperature
2) relative humidity
3) wind speed and direction
4) state of the weather
5) fire and 10-hour time-lag fuel moistures
6) atmospheric stability
7) prediction of storms or fronts
8) antecedent precipitation

As prescribed fire finds wider application more refined and rigorous prescriptions will evolve. Successful use of prescribed fire depends on careful planning and decision making. It also depends on careful prescriptions of weather and fuel conditions which may occur infrequently.

Fire in the Black Hills

Fire History

Research conducted by Thompson and Gartner (1971) concluded that the pine stands in the Black Hills have become much more dense since the 1870's. There were trees of sawlog size averaging 12 to 20 inches in diameter in the 1870's (Dodge, 1965). Logging has removed the larger trees and the second growth stands are overly dense due to increased fire protection.

Gartner and Thompson (1972) studied the logs of early explorers and they have little doubt that fire was an important environmental and biological factor in this area. Wildfires, started by lightning storms are credited with periodic destruction of pine stands, and creating the open forests, while maintaining healthy stands of pine. Biswell (1972) has long held that the relatively fireproof, thrifty, open aboriginal ponderosa pine forests were created and maintained by the periodic and natural occurrence of light surface fires in much of the West.

The role of fire has been reduced by fire protection, but certainly not eliminated. Large fires continue to occur in the Black Hills. In a period from 1969 to 1972, no large fires occurred. In the average year, 83 fires burned only 91 acres. However, 162 fires burned 3,321 acres in 1974. Fifty-seven large fires have occurred in the last 65 years.

Timber Stand Description

The Black Hills are a forested island in the vast expanse of the Northern High Plains, covering approximately 5,150 square miles in southwest South Dakota and northeast Wyoming (Orr, 1975). Ponderosa pine is the dominant species of the area. Pine stands in the Black Hills cover about 1.4 million acres of land, and vary from overstocked pole stands with 5,800 stems per acre to open, park-like stands with large, widely spaced trees with grass as an understory (Alexander, 1974). The environment of the pine forests has been drastically altered since the 1870's, due to intensive timber management and fire suppression. Denser stands of pine seedlings and poles have been created which are less desireable than sawtimber. Settlement of this area has also created a patchwork pattern of land ownership with recreational sites, homes, and ranches scattered throughout the forested area. This makes optimum fuel management difficult, whether by fire or any other means.

Prescribed Burning Climatology

Before any discussion about the frequency of favorable burning conditions can be made, an understanding of the climatology of the Black Hills is necessary.

Johnson (1949) presented a climatological review of the Black Hills, and most of the information described below is taken from his work.

General Climatic Influences

The Black Hills region has a continental type of climate, characterized by high daytime temperatures and low temperatures at night, comparatively cold winters and warm summers, moderate precipitation, low relative humidities, and abundant sunshine. Cold fronts are most frequent in December, January and February, with the winters often "open", and little cold until late December or even January. There is a gradual increase in normal temperature upwards from about the first of March to the first of August, with the average monthly temperature highest in July. Heat waves are possible, but rather infrequent to this area. Temperatures of 90 degrees or higher frequently occur during the months of June, July, August, and September.

Precipitation comes in the spring and summer months, while late fall and winter have light rains. At higher elevations snow occurs from October to April. The least amount of precipitation usually occurs in February, after which there is a gradual increase in the normal monthly amount until June. After June there is a steady decrease in precipitation to the end of the year. The heaviest monthly amounts usually fall in May, June and July, while the winter months have the least precipitation. Heaviest snowfalls are generally in March. Snowfall is light during the winter months, except at higher elevations as high winds leave most exposed areas bare of snow cover. Thunderstorms are common in the summer, and there are few days in which a thunderstorm doesn't occur at one place or another in the Hills region. In many of the thunderstorms in the region the moisture is evaporated and never reaches the ground, resulting in the dry thunderstorm.

Cold fronts are frequent to this region. In the 10 years that were included in this study the month of October had the highest number of cold fronts occur with 69. This was 12% of the total fronts to pass through the Black Hills region. The next highest occurrence was in September with 57 or ~~and~~ 10% of the total. Data is given in Table 1.

General Burning Conditions

The general burning conditions for each season will be briefly stated below. These burning conditions will be given for Fall, Spring, and Summer. Winter is excluded due to the probability of snow cover at the higher elevations, but in foothill areas prescribed burning may be a possibility in winter.

Table 1. Cold front data for 1964-1973. Given are the number of cold front passages for each month for each year.

Month	Days	64	65	66	67	68	69	70	71	72	73	Total	$\bar{x}$	S
Jan	31	6	6	5	5	6	0	4	4	6	5	47	4.7	1.83
Feb	28	5	4	4	3	4	0	4	2	3	5	34	3.4	1.51
March	31	5	3	7	6	5	2	4	6	3	3	44	4.4	1.65
April	30	5	6	4	2	6	4	5	5	6	4	47	4.7	1.25
May	31	6	5	3	3	6	5	4	7	5	5	49	4.9	1.29
June	30	3	7	3	5	5	2	5	7	7	4	48	4.8	1.81
July	31	4	3	3	4	4	6	5	7	5	5	46	4.6	1.26
Aug	31	8	5	6	5	4	4	6	4	6	4	52	5.2	1.32
Sept	30	6	5	4	7	5	5	5	8	6	6	57	5.7	1.16
Oct	31	6	8	6	8	6	5	7	7	9	7	69	6.9	1.20
Nov	30	6	5	6	8	5	5	5	5	5	4	54	5.4	1.07
Dec	31	2	4	3	5	3	3	8	6	3	6	43	4.3	1.89
Total		62	61	54	61	59	41	62	68	64	58	590		

Fall

The fall season generally is the months of September, October, and November. There is generally a decrease in monthly precipitation during these months, and temperatures are decreasing also. During this period relative humidity ranges from around 10% to 50% on an average with several days with higher relative humidities. Fuel moistures range from 2% to 31%, with an average of about 9%-11% depending on location. Temperatures decrease during this period, but are pleasant and comfortable. In general then the burning conditions for fall are: 1) decreasing temperatures, i.e., cooler than summers; 2) low to no precipitation; 3) low relative humidities; 4) low fuel moistures.

Spring

Spring is usually a time of highest amounts of precipitation. The weather records for the 10 years that were studied showed high fuel moisture throughout the spring. The one-hour timelag fuel moisture ranged from 2% to about 31% with an average of 17-18%. Relative humidities average about 51% during the spring time for the years 1964-1973. The spring also brings about new growth of understory vegetation, so there will be higher percent green material at this time of year. In summary then the general burning conditions for spring are: 1) high fuel moistures, both 1 and 10 hour timelag fuels; 2) high relative humidities; 3) higher amounts of precipitation; and 4) higher percentage of green material or fuels.

Summer

The summer season June, July, and August usually brings an increase in daytime temperatures. With that is an increase in evaporation which will affect fuel moistures. June and July do have high precipitation amounts, but August is hot and dry. This hot, dry period is characterized by lower fuel moistures as compared to spring, and lower relative humidities. Relative humidities are relatively high 20%-80% range during June and July. In August relative humidity drops, ranging from about 9% to 40%. Summarizing the general burning conditions for summer: 1) high temperatures; 2) high relative humidity in June and July, but lower in August; 3) fuel moistures are high when relative humidity is high in June and July, and lower in August. August is also the month of highest fire danger in the Black Hills.

Chapter 2. Fuels in the Black Hills

Fuel Models

In a report written by Bob Steele entitled "Possible Prescriptions for Prescribed Fire in Several Fuel Types of the Blach Hills"[1] (see Appendix E), several fuels were found in the Black Hills area that can be characterized by fuel models of the National Fire Danger Rating System, NFDR, (Deeming, et al., 1972). These fuel models were taken to be the candidate fuel types for burning in the Black Hills.

Fuel Model A

Fuel type A characterizes grasslands, where the primary carrier of fire is a continuous bed of fine fuels (Deeming, et al., 1972). Due to the prevention and control of wildfires, grassland openings in the Black Hills are slowly being invaded by ponderosa pine. Burning is considered here as a management practice to maintain the meadows for forage and aesthetic quality.

Fuel Model C

Fuel type C represents logging and thinning slash (Deeming and Brown, 1975). The results of thinning ponderosa pine (especially pre-commercially) can be moderate to heavy fuel loadings, as much as 20 tons per acre or more (Fahnestock, 1968). This slash presents a fire hazard and should be removed or treated, so as to reduce this hazard and prevent losses in case of wildfire.

Fuel Model E

Fuel type E is used for the overstocked or closed canopy pine stands. It is the model which best fits the situation in the Black Hills. These areas are crowded (doghair stands, with much reproduction, but not very vigorous growth). Fuels are composed of needles, twigs, limbs, some grass, and an occasional down log or remnant of the past forests. Table 2 gives a comparison of fuel loadings, surface-to-volume ratio, and fuel bed depths for each fuel model.

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[1] Steele, Bob. Dec. 1, 1974. "Possible Prescriptions for Prescribed Fire in Several Fuel Types of the Black Hills." Eisenhower Consortium Progress Report, Contract No. 16-471-CA.

Table 2. Fuel model input parameters for the NFDR fuel model, taken from Rothermel (1972).

Fuel Types	Fuel Model	Total Loading (tons/acre)	Fine		Medium		Large		Living Fuel		Fuel Depth
			σ	Wo lb/ft^2	σ ft^{-1}	Wo lb/ft^2	σ ft^{-1}	Wo lb/ft^2	σ ft^{-1}	Wo lb/ft^2	ft.
Grass (short)	A	.75	3,500	.034	--	--	--	--	--	--	1.0
L gging slash medium)	C	120.0	1,500	.184	109	.644	30	.759	--	--	2.3
T ber litter)	E	15.0	2,000	.069	109	.049	30	.115	--	--	0.2

Burning Objectives

Fuel Model A

When it is desirable to maintain grasslands that are being invaded by pine seedlings, fire can be used to burn both the grass and the pine seedlings. The grass will return to the area because the roots are not killed, while the pine seedlings are killed. A high intensity fire is desired to produce the greatest tree mortality.

Fuel Model C

Fire is used in logging or thinning slash to remove the fire hazard caused by the slash, or as a method of slash treatment. The slash burning can be done either by piling and burning, or by broadcast burning. Thus by treating or removing the fire hazard, losses can be minimized in the occurrence of a wildfire in the logged or thinned area. Fire must spread in the slash, but be of low enough intensity or short enough duration to minimize tree mortality.

Fuel Model E

The objective in overstocked, closed canopy pine stands is to use fire as a thinning agent. Cambial heating and crown scorch are ways in which the smaller suppressed trees might be killed. Fire intensity would be defined by fuel and weather conditions. A fire would be useful here to cover large areas with minimal cost of both time and money.

Approaches for Decision Making

Fuel Models

The use of fuel models is a means of organizing the required fuel information for input into the mathematical fire spread model developed by Rothermel(1972). The fuel model is a simulated fuel complex for which all the required fuel descriptors have been determined; it consists of a complete set of fuel parameters required for solution of the mathematical model (Deeming, et al., 1972). These fuel models are useful for large scale planning, i.e., determining the number of days available for burning on the forest in a general fuel type. Fuel models are not useful on specific sites for prescription development. In this study we have used fuel models:

1) in the absence of better data of a general nature on fuels representative of the area.
2) to facilitate the use of burning index or other NFDR components as prescription parameters.

If weather and fuel moisture parameters only are used in the prescription, the procedure for determining the number of favorable days does not need a fuel model input. The use of a fuel model allows one to write prescriptions including rate of spread (spread component), energy release rate (energy release component) and/or flame length (burning index), and determine the number of days favorable for burning based on a range of those prescribed variables.

Fuels and fuel models can be described or characterized by several descriptors, such as surface-to-volume ratio, fuel loading, fuel bed depth, moisture content, heat content, and several others. These descriptors may be used for comparisons of two different fuel types or models. Table 2 shows the survace-to-volume ratio (σ), fuel loading (Wo) and fuel bed depth for each of the three fuel models used in this study (Rothermel, 1972).

Field Data

During the summer of 1975 fuel inventory information was gathered on three small areas which are scheduled for prescribed burning. These areas are all found in the Elk Mountain Ranger District, near the Tepee work center and weather station. The inventory data is presented in Table 3.

Comparing the fuel descriptors for logging slash with those of the actual field data we find some differences, and some similarities. The model gives only 1 loading value and one surface to volume ratio value for fine fuels. The

Table 3. Fuel inventory data from Elk Mountain District, Black Hills National Forest.

	AREA #1[1]						AREA #2[2]						AREA #4[2]					
	DC1[3]	DC2	DC3	DC4	DC5	LC1[4]	DC1	DC2	DC3	DC4	DC5	LC1	DC1	DC2	DC3	DC4	DC5	LC1
OADING(lb/ft^2)	.003	.194	.0134	.2935	.2449	.006	.002	.105	.016	.180	.256	.004	.001	.137	.012	.207	.314	.005
URFACE-VOL ATIO	4240	1755	282	94	28	4240	4240	1755	282	94	28	4240	4240	1755	282	94	28	4240
UEL BED EPTH (AVE)	.46 ft.						.32 ft.						--					
LOPE	3%						8%						--					

[1] Data based on 15 plots

[2] Data based on 5 plots

[3] DC = Dead Class
DC1 = Dead grass and forbs
DC2 = Needles
DC3 = 0-1/4 inch
DC4 = 1/4-1 inch
DC5 = 1-3 inches

[4] LC = Live Class

field data gives three different values for three classes of fuels which could be defined as fine fuels. The fuel loading values for the first three dead classes, then summed yields a value of .21 lb/ft^2, while the model has a value of .18 lb/ft^2. The field data gives surface to volume ratios for each of the three classes of fine fuels. Each one is given in Table 3. The fuel model value for surface to volume ratio for fine fuels is 1500. This value varies greatly from the values given in Table 3. For the other fuel size classes the surface to volume ratios are fairly close together, while the loading values are different. Loadings for field data of medium size or the 1/4 - 1 inch size fuels is .29 lb/ft^2 while the model value is .64 lb/ft^2. This is a difference of .35 lb/ft^2. The values for the large size class have a difference of .51 lb/ft^2, with the model value being the greater. Fuel bed depth values also have a large difference, again the model value is the larger.

It would appear that the fuel model gives higher values for the input parameters to Rothermel's fire spread model. The fuel model input parameters yield different values for rate of spread, reaction intensity, and flame length, than do the field data input values. Actual field inventory data would provide better descriptor and/or input values for the fuels that are on the ground, but the fuel model values can be used as a good first approximation.

Figures 1 through 4 show the fuels that were inventoried in the Black Hills.

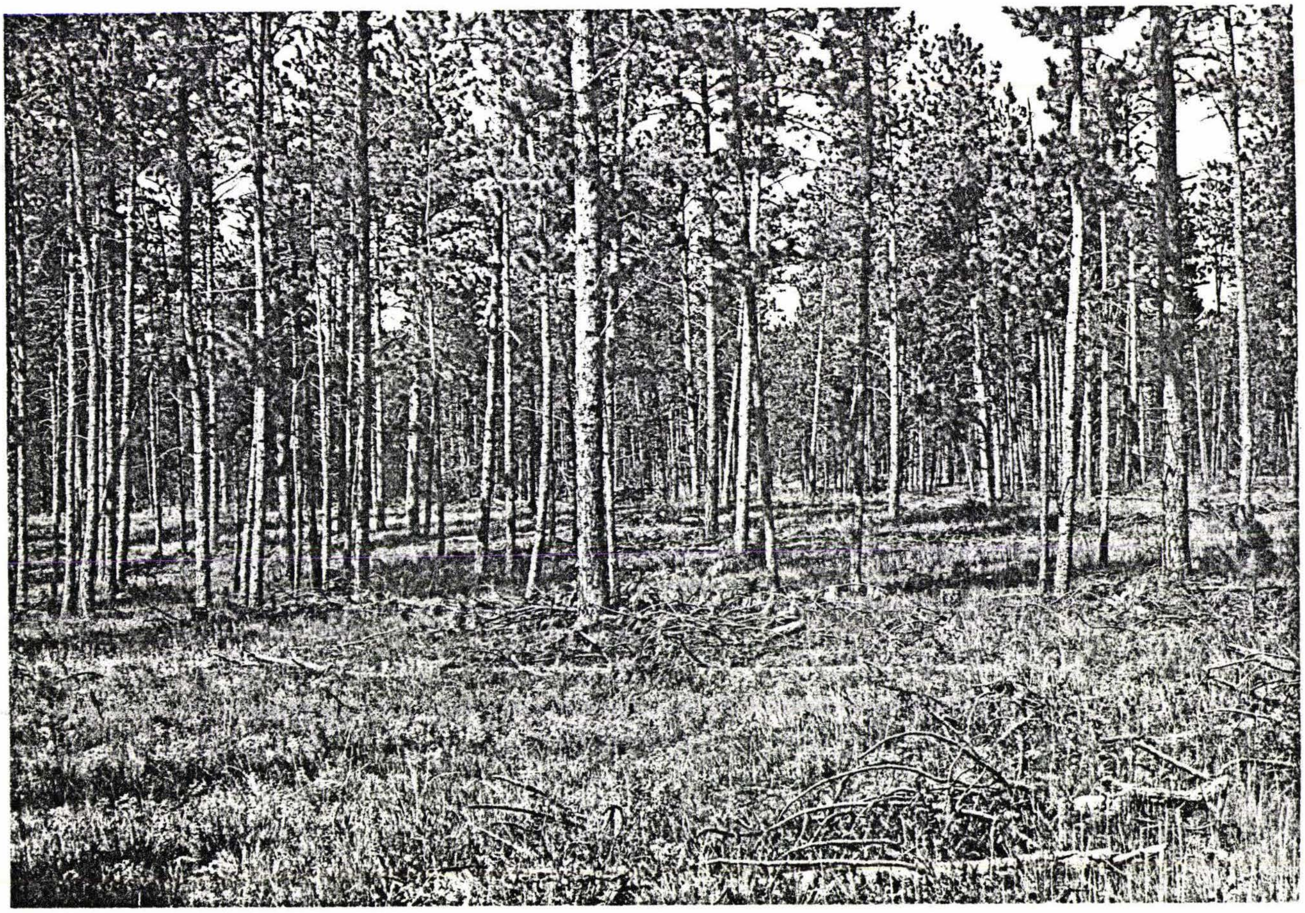

Figure 1. Ponderosa pine stand which contains area 1, showing thinning slash and grass understory. Stand thinned using selective-cut method.

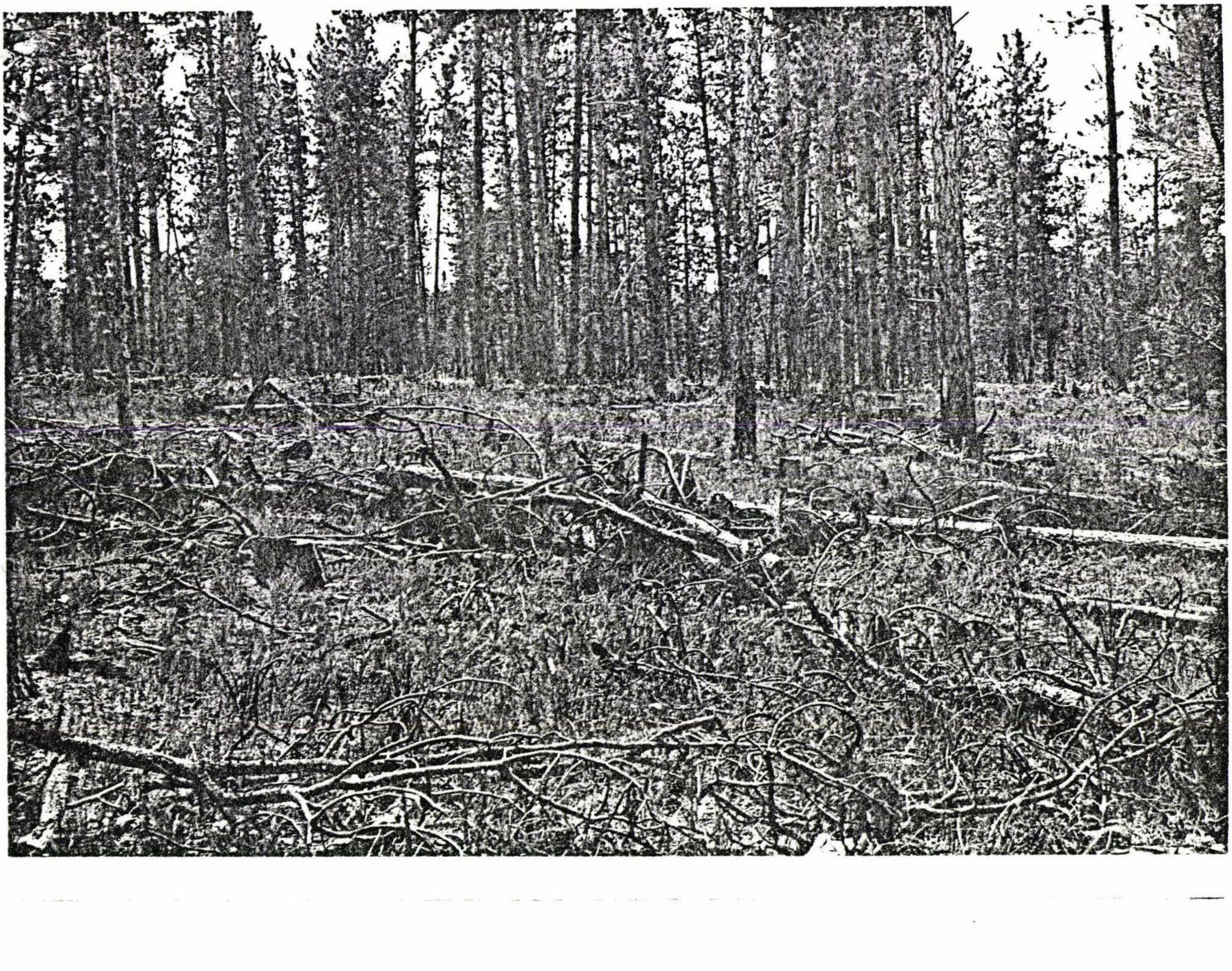

Figure 2. Area 1 looking south. Thinning slash and grass understory shown.

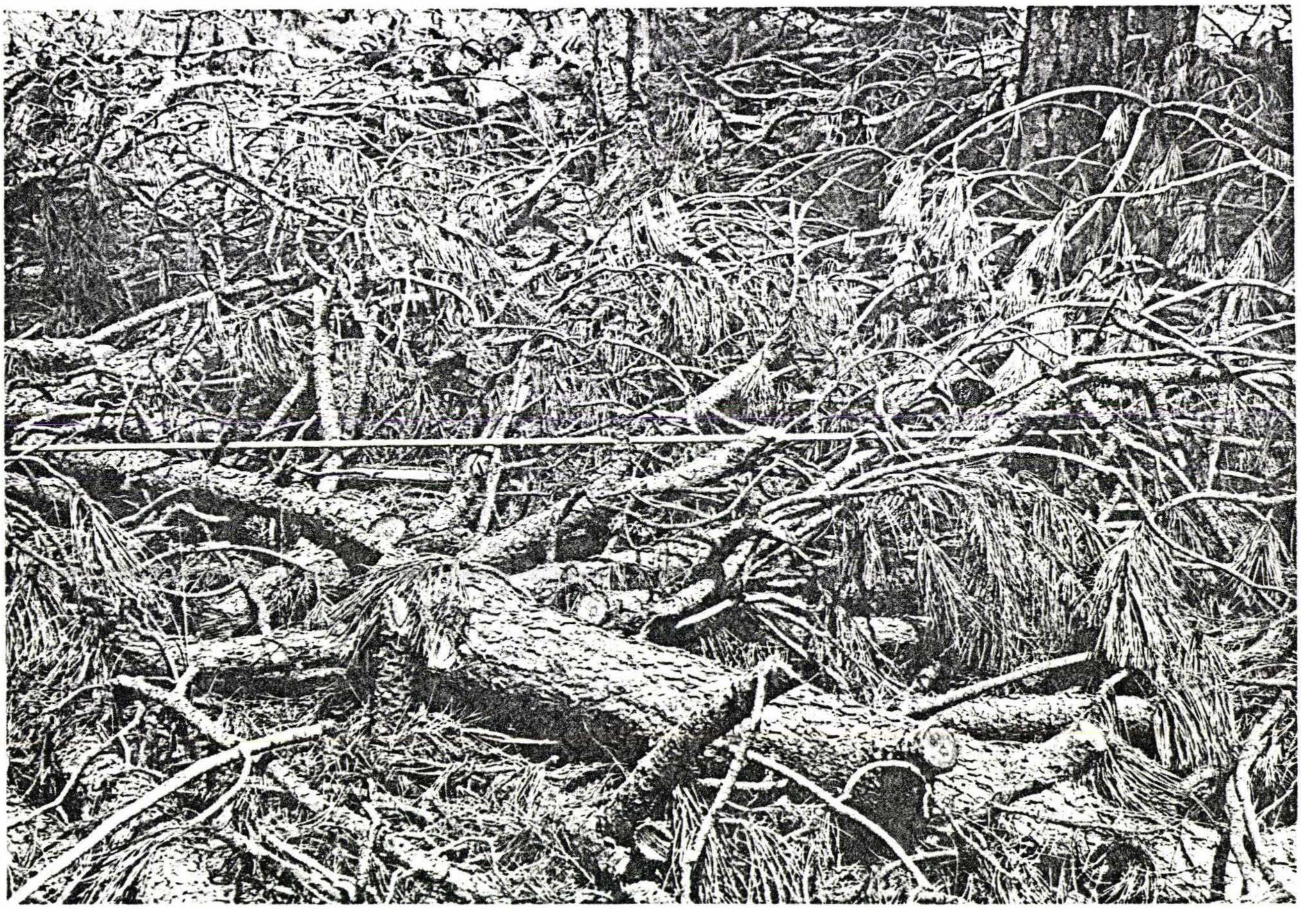

Figure 3. Example of slash concentrations in area 1. Inventory rod used as size comparison (rod is 6 feet in length).

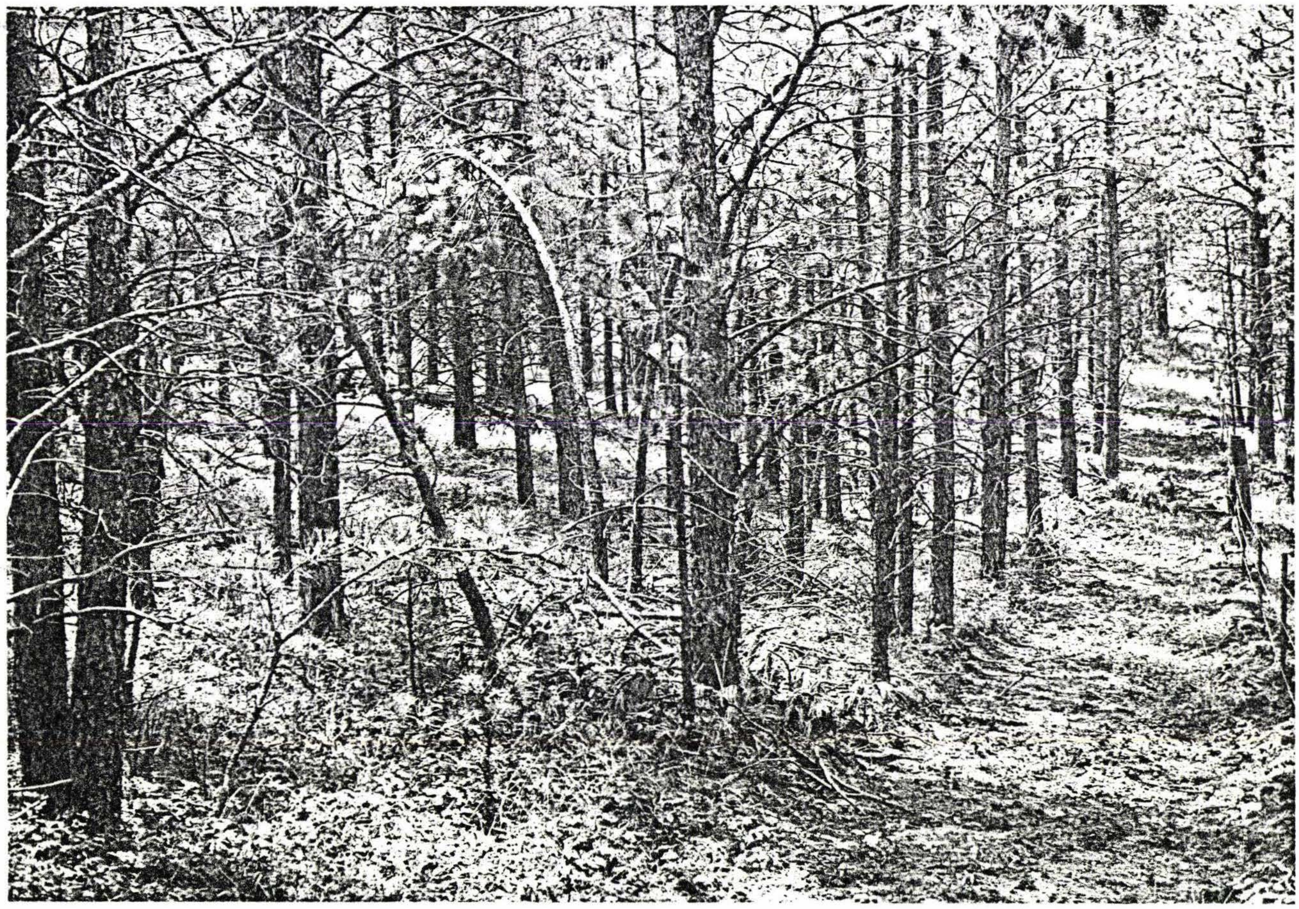

Figure 4. Area 2. Catline seen in lower righthand corner.

Chapter 3. Study Methods

Objectives of Study

The principal objective of this study was to determine the frequency of favorable conditions for prescribed burning in the Black Hills. Other objectives reached in the study were to:

1) define candidate fuel types for prescribed fire
2) describe the successful results in each fuel type
3) describe the weather and fuel conditions necessary to achieve the successful results
4) describe the sensitivity of possible number of burning days to each prescription.

In the following pages we will attempt to discuss the methods used to reach these objectives.

Fuels

Fuel Models

One of the first things to do in any prescribed burning planning is to select the fuel or fuels in which the manager wishes to burn. As part of this project Bob Steele defined the candidate fuels in the Black Hills. He described these fuels as being similar to the fuel models A, C, and E as defined in National Fire-Danger Rating System (Deeming, et al., 1972). Steele's report appears in Appendix E. Fuel model B was also listed in Steele's report, but was later eliminated, because fuel model B is not in the Black Hills fire plan.[1] Each fuel type has been described in Chapter 2.

Fuel models were used in this research study for three main reasons. They characterize and standardize the fuels present, they are the best representation that we have of the fuels, and they are compatable with the program FIRDAT (Furman and Helfman, 1973) and the NFDR indexes can than be used as prescription parameters.

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[1] Personal correspondence with J. E. Sanderson, Director of Fire and Avaition Management, USDA Forest Service, Region 2 (retired).

Field Data

In Chapter 2, comparison between the use of fuel models and specific fuels data was made. The specific field data was collected in the Elk Mountain Ranger District, near the Tepee work center. Three small areas were sampled for the comparison. Two might be catagorized as fuel model C and one could be described as fuel model E. There was no sampling in fuel model A. Area #1 is a stand of mature ponderosa pine that received a shelterwood cut. It is approximately 3 acres in size. Area #2 is about 1 acre in size, and is an overstocked, doghair stand of immature ponderosa pine (poles and saplings). Area #4 is a stand of immature pondersoa, that has received a precommercial thin. Sampling was done in each of these stands for the comparison. There were 15 plots taken in Area 1, 5 plots in Area 2, and 10 in Area 4.

Fuel inventory was performed using the planar intersect method as outlined by Brown (1974). This method for inventorying downed woody material was used in each plot. Duff, litter, grass and forb measurements were taken and collected according to methods outlined by Brown[2/] for the White Cap study in the Selway-Bitterroot Wilderness Area.

The materials collected were taken to the Rocky Mountain Forest and Range Experiment Station, where sample bags were oven dried for 24 hours at 105°C. The oven dry weights were obtained for duff, litter, grass, and forbs. This data, combined with the woody fuel data were used to calculate fuel loadings, surface to volume ratios, etc., for each fuel size class, for each area. The fuel loading and other data have been presented in Chapter 2. These data were also used to calculate the fire behavior parameters and construct the graphs in Appendix D.

Prescription Development

Weather and Fuel Requirement

The burning prescription is the part of the burning plan which states the fuel and weather requirements under which a prescribed fire will be carried out. A prescription was the basis for, and one of the main inputs into, program FIRECOR (detail presented in Chapter 4). It is this prescription against which the records of past weather at each station were checked to obtain the frequency

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[2/] Brown, James K. 1974. Fuel and Vegetation Inventory Procedures -- White Cap Study. USDA Forest Ser., Unpublished report on file with the Fuel Science Research Work Unit, Northern Forest Fire Laboratory, Missoula, Mont. 11 p.

of favorable burning conditions.

A prescription can have as many or as few parameters as desired (up to 20), but for the purpose of this study only 5 or 6 were used. There were: (1) burning index (BI); (2) temperature (air); (3) relative humidity; (4) wind speed; (5) 1 hour timelag fuel moisture, and (6) 10 hour timelag fuel moisture. These prescription variables were then input into the program, having high and low values. These values were then checked against the weather records, and if the range of values given were not met on any one of the parameters the day was eliminated.

The desired variable, adjusted fine fuel moisture, which considers the condition and loading of herbaceous fuels was not used as a prescription parameter in this study. The historic fire weather station data does not include reliable data for herbaceous fuel condition during the period of record. It is anticipated that future use of the methodology presented herein can use herbaceous fuel condition to advantage as a prescription variable, especially in the grasslands fuel type (NDFR fuel model A).

Initial Prescriptions

Initial prescriptions to be used as input into the program were developed by Bob Steele, in his preliminary report, "Possible Prescriptions for Prescribed Fire in Several Fuel Types of the Black Hills." These prescriptions were developed from suggestions and ideas from Forest Service personnel and from prescriptions used by SWIFCO.[3/] Further contact with Forest Service experts was used to develop the prescriptions used in the initial computer runs. Some experts approved the prescriptions as being adequate, while others said the values were too high, and still others said they were too low. These initial prescriptions were used as a starting point to obtain the frequency of favorable burning conditions. Prescriptions were written for each fuel model, and are presented in Table 4. Each of these prescriptions were input into the program FIRECOR, and checked against the weather records. The initial prescription in fuel model C did not yield many days, while in model E there were not any days which met the original prescription. In fuel model A, the initial prescription

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[3/] 1968. Guide to prescribed fire in the Southwest. Southwest Interagency Fire Council, University of Arizona.

yielded many satisfactory days. From the output of the initial runs, it became obvious that the range of values for some of the parameters would have to be widened if a significant number of burning days were to be found.

Table 4. Initial burning prescriptions for each fuel model.

	Initial Burning Prescriptions		
Parameter	Fuel Model A	Fuel Model C	Fuel Model E
Burning Index	0-12	0-30	0-25
Temperature	70°-90°F	65°-85°F	70°-80°F
Relative Humidity	10-25%	15-50%	20-30%
1 hour fuel moisture	0-12%	10-25%	15-25%
10 hour fuel moisture	--	10-30%	15-20%

Potential Fire Behavior

Fire behavior parameters, rate of spread, reaction intensity, and flame length for each fuel model were calculated and graphs constructed based on Rothermel's (1972) spread model. A program developed by Frandsen (1973) and Andrews[4/] for the Hewlett-Packard 9820 of this spread model was used for the calculations. The program is on a cassette tape, and is stored in the computer memory. Data is input through a series of key strokes, and the results are a plotted graph, such as those in Appendix D. These graphs were used to estimate potential fire behavior through a range of wind velocity and fuel moisture values. Trial prescriptions were then written, based on the wind velocities and fuel moistures that would produce acceptable fire behavior in the idealized fuels.

Weather Data

The fire-weather records for five weather stations located in the Black Hills National Forest were obtained from the U.S. Forest Service. These five stations are at Nemo, Cheyenne Crossing, Custer, Tepee, and Hot Springs. These

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[4/] Andrews, Patricia L. 1975. Fire Spread Model with Plotting. On file, Northern Forest Fire Laboratory, Missoula, Mont.

data were input from a magnetic computer tape on file at the Colorado State University Computer Center and at the USDA Computer Center at Fort Collins (Furman and Brink, 1975) to the computer program FIRDAT (Furman and Helfman, 1973) and output to another magnetic tape along with the computed NFDR indices and components. Each station and fuel model type was labelled for easy access.

The weather data used was taken at the weather stations at 1 p.m. Therefore a day that will pass a prescription will be identified as satisfactory for burning only if the prescription was met at the weather station and at midday.

Prescribed burning is not recommended on a day in which a cold front passes or is predicted to pass the area. Cold front data for this research was obtained from daily weather map evaluation. "Weatherwise"[5] was used as a source of surface pressure maps from January 1964 to April 1968, and from July 1969 to October 1973. "Daily Weather Maps-Weekly Series"[6] provided maps for May 1968 to June 1969 and for November 1973 to December 1974. Identification of frontal passages was subject to some interpretation. Only cold and occulded frontal passages were noted, while warm front passages were ignored. The maps indicated weather conditions at 24 hour intervals, so it was sometimes difficult to determine if marginal fronts did indeed pass over the Black Hills. This cold front data was typed onto data cards in a series of 1's and 0's, with 1 indicating a day which a cold front passed. This data was then added to the magnetic tape file with the weather station data from FIRDAT.

Program FIRECOR

Program FIRECOR was used to obtain the frequency of favorable burning conditions. The detail of FIRECOR is discussed in Chapter 4, but briefly FIRECOR does three jobs. These are:

1) Checks weather data against a prescription
2) Checks days which met prescription against days on which a cold front or occluded front passed over the area
3) Categorizes the days which were not eliminated in 1 or 2 above by 10 day periods.

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[5] Published bimonthly for the American Meteorological Society, 45 Beacon Street, Boston, Mass. 02108

[6] Printed weekly by the U.S. Department of Commerce, NOAA, Environmental Data Service. Public Documents Department, USGPO, Washington, D.C. 20402

The program was specifically developed for this research, written in Fortran IV computer language, and designed for a CDC 6400 computer. It is constructed with overlays, so that less computer central memory will be used. Three main subprograms comprise the program and there are several subroutines.

Initial prescriptions for each fuel model were run through this computer program. Values or ranges of values were varied for each parameter. By varying the parameter values and making several runs, a rough estimate of the sensitivity for each parameter was obtained, the most limiting factor or parameter was found and the prescription which gave the maximum number of days was identified.

The output from the computer program consisted of:

1) A list of weather records which meet the prescription
2) The record which caused a string of days to be terminated, followed by the parameter(s) which caused termination
3) The prescription, the number of records read, the number of records which met the prescription, and the percentage of days that met the prescription
4) The number of days eliminated by cold front passage
5) Three tables of 10 day information
    a) a table of the number of days of record for each 10 day period for each year
    b) a table showing the average number of days per year, standard deviation, complete 10 day periods, and total days for each year the met the prescription
    c) a table showing total, average, and standard deviation of the number of satisfactory days for each 10 day period for the entire 10 years

See Appendix B for example output. The results are presented and discussed in Chapter 5.

Chapter 4. Computer Program FIRECOR

Program Development

Reason for Program

The program FIRECOR was developed to compare archived weather records from the national fire-weather station network against a prescription input of any combination of weather observations, fuel moistures and computed fire danger indices. It was used to determine the number of days in each ten day period of the year that are satisfactory for burning under several given prescriptions. The average and standard deviation about the mean were also computed. FIRECOR was written by Russell Lewis, of the Fire Science program at CSU.[1/]

Ideas Incorporated into Program

Basically, FIRECOR has three main subprograms. The first subprogram compares the daily weather data from FIRDAT to the input prescription. The program checks the range of prescribed values against each weather record and/or danger rating index. If one prescribed parameter is not met then the day is disqualified. The next subprogram checks the days that met the requirement in the previous subprogram against a list of days of observed cold front passages. If a day met the prescription requirement, but a cold front passed through the area on that day, then it too is eliminated. The third subprogram sorts the days into ten day periods. Satisfactory days in each ten day period are summed over the available period of record and a total number of satisfactory days is obtained; the mean number of days per year and the standard deviation is calculated.

Program FIRECOR

Program Structure

Overlays - The program is designed using overlays. The overlay is a Fortran IV method whereby memory core space is saved. FIRECOR uses a large amount of core space in the computer, if it is divided into subroutines. But with overlays

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[1/] Russell Lewis was a computer programmer, formerly employed by the Fire Science Program at Colorado State University. He is with the U.S. Bureau of Reclamation at Grand Junction, Colorado.

this core memory is cut to 49,000. The program was originally written as three separate subprograms, and each subprogram has several subroutines. Each program and subroutine will be discussed later.

A program called DRIVER is used to sequentially call the three subprograms (see Appendix A for program listing). The subprograms are titled: 1) Prescribed Fire (PREFIRE), 2) Frontal Passage (FRNTPSG), and 3) Ten Days (TENDAYS).

1. PREFIRE

Program PREFIRE is a Fortran IV program designed to compare archived weather records against a prescription.[2/] A prescription data card is input for each prescription parameter. The program checks the weather records against each prescription parameter in ordered preference, designated by a constraint number input on each parameter data card. Each weather record that falls within the prescribed ranges is then printed. The next record is read and checked. If the record doesn't meet the prescription parameters it is ignored and the next record is read. The weather records for an entire period (10 years) are checked in this manner. The prescription, as input is printed and the percent of days which passed the prescription are computed. The program can search the records of more than one weather station using the same prescription; or more than one prescription can be input into the program, and compared with the weather records of one or more weather stations in one computer run.

PREFIRE has one subroutine. This subroutine builds the format through which the data is read and printed. The subroutine has been designed to cope with the varying column locations and lengths on the weather tapes. Each time a new prescription is input a new format is built into the program by the subroutine. The variables for PREFIRE are listed in Table 5.

2. Coldfront Passage

Cold front passage (FRNTPSG) is the second subprogram of the FIRECOR program called from the program DRIVER. It is a Fortran IV program designed to check the days that satisfied the prescription in PREFIRE against a list of days on which a cold front or occluded front occurred over the Black Hills. The number of days read are output, along with the number and percentage of days eliminated.

[2/] Refers to weather records obtained from the program FIRDAT.

Table 5. Variable list for PREFIRE.

Variable Name	Array/Dimension[3]	Description
*NAMEV	Yes/20	Alpha-Numeric name for a variable within a prescription ≤10 characters
*ICOLB	Yes/20	The column from weather data (tape) In which the variable value begins
*ICOLE	Yes/20	The column from weather data in which the variable value ends
*IVFMT	Yes/20	The field format through which the variable's value is to be read; F-type
*VLO	Yes/20	The lowest value the variable can have to satisfy the prescription
*VHI	Yes/20	The highest value the variable can have to satisfy the prescription
*ICONST	Yes/20	The constraining order of the variable
FMT	Yes/80	The format generated by PREFIRE through which a complete weather record is read
FLD	Yes/135	The array into which weather data is read
IFLDREF	Yes/20	This array serves as a cross-reference to FLD so that FLD (IFLDREF(1)) is the field containing the value of the first prescription variable
NCON	Yes/20	This array serves as a cross-reference to FLD so that FLD (IFLDREF(NCON(1))) is the field containing the value of the most constraining variable of the prescription
FMTO	Yes/81	Same as FMT but for output
NFILE	----	Counter of the present file being read from weather data
NPRE	----	Counter of the present prescription

---

[3] This column distinguishes whether the variable is an array or not. "Yes" indicates that it is an array, and the number is its dimension.

* Indicates input variable.

Table 5. (Continued)

Variable Name	Array/Dimension	Description
*NCHARS	----	The number of characters from weather data (usually 80)
*N	----	The number of variables in the prescription; up to 20
*NDSETS	----	The number weather data sets, i.e., the number of files on tape 1
*NPRESC	----	The number of prescriptions to be processed
NTFILE	----	The total number of files written to tape 2
*NAMEF	----	Alpha-numeric name of the fuel model ≤10 characters
*ISTNNO	----	The number of the station
*NAMES	----	The name of the station
*IPRF	----	A print flag if=1, day satisfying the prescription aren't printed; otherwise printed
NWR	----	A counter of the number of weather records read
NSD	----	A counter of the number of days satisfying the prescription
PDF	----	Previous day flag. If=1, the previous day satisfied the prescription, otherwise it did not
NFLDS	----	The number of fields within one weather data record
NC	----	The number of the variable with the present order of constraint
NFLD	----	The number of the field containing the above variable
PSD	----	The percent of days satisfied to total days

FRNTPSG has one subroutine. It is called Load Matrix or LOADMAT. It loads a matrix, ICFD, with cold front data, previously stored on magnetic tape. The variables used in FRNTPSG are listed in Table 6.

3. TENDAYS

The third subprogram called from the program DRIVER is titled TENDAYS. TENDAYS is designed to sort by 10 day periods the days which have not been eliminated by PREFIRE and FRNTPSG. The 36 ten day periods begin January 1 and end December 26. The total number of days for each year is computed and output. The average number of days per 10 day period is also computed, along with the standard deviation about the mean. Each 10 day period is then summed over the whole 10 years to obtain a total for each ten day period. This is also averaged and a standard deviation calculated. The comments all, part, or none, appear in the output. This allows the user to see if everyday of a particular 10 day period was included in the weather record, or part of it or none of it. TENDAYS is designed to operate on 1 or more weather stations. All it needs for this is the data necessary for each station.

TENDAYS has several subroutines, the first of these being Initialize or INIT. The function of this subroutine is to initialize the arrays and variables to zero. It also places "none" into the comments array. The second subroutine is called Get Index or GETNDX. Subroutine GETNDX generates the indexes[4/] used in TENDAYS. These indexes are used by the program to sort and tabulize the days as they are placed in the 10 day periods. The third subroutine is called FIXIT. FIXIT is designed to set the array matrix index to zero and the comment matrix to "part". INIT or FIXIT are called depending on which comment or value is needed in the program. The next subroutine is called Printer or PRINTR, whose function is solely to print the information computed onto paper. A subroutine called statistics or STAT is called from TENDAYS. Subroutine STAT computes the total, average, and standard deviation for each of the 10 day periods over the entire 10 years. This information is also output by this subroutine. One subroutine titled WHY is called by the subroutine STAT. WHY is used to initialize the variables used by STAT. The variables used in TENDAYS are listed in Table 7.

[4/] Indexes used to locate the different values stored in the array, matrix.

Table 6. Variable list for FRNTPSG.

Variable Name	Array/Dimension	Description
*ICFD	Yes (10,12,13)	Cold Front passage data
*IFILDES	Yes (20,3)	Station and fuel model names
*IDUM	Yes (8)	Station numbers and weather data
NFILES	----	Number of files
NFILESRD	----	Number of files read
NRECSRD	----	Number of records (weather) read
NRECSEL	----	Number of records eliminated
IY	----	Year
MO	----	Month
ID	----	Day

Table 7. Variable list for TENDAYS.

Variable Name	Array/Dimension	Description
Matrix	Yes/10,36	Array for storing the output data of ten day periods, ten years, 36 10-day periods
*ITITL	Yes/8	Station name for which TENDAY is being run
*IMB	Yes/10	Month in which weather information records begin
*IME	Yes/10	Month in which weather information records end
*IDB	Yes/10	Day on which weather information records begin
*IDE	Yes/10	Day on which weather information records end
ICOMNT	Yes/10,36	Array in which comments all, part, or none are stored
SUM	Yes/10	The sum of all the days which passed prescription for each year.

Table 7. (Continued)

Variable Name	Array/Dimension	Description
SSUM	Yes/10	The standard deviation about the mean number of days/10 day period
CT	Yes/10	Complete 10-day periods
AVE	Yes/10	The mean number of days/10-day period
NDSETS	----	Number of data sets (3-5)
IY	----	Year
MO	----	Month
ID	----	Day
IDM	----	Index for month
IFD	----	Index for day
INDX	----	Index
IYNDX	----	Year index
NDXB	----	Index of beginning day
NDXE	----	Index of ending day
INCB	----	Increment beginning
INCE	----	Increment ending
IS	----	Operational variable
IE	----	Operational variable
Variables used in subroutine STAT		
M	Yes/10,36	The matrix from TENDAY. To be summed
SUMX	Yes/36	Sum total for each 10 day period
SUMX2	Yes/36	Sum total of each 10 day period squared
SSUMX	Yes/36	The total sum, squared
XBAR	Yes/36	The average for each 10 day period
SS	Yes/36	The variance for each 10 day period
S	Yes/36	The standard deviation for each period
N	----	Number of years considered (n=10)
IDP IDP2	Yes/36	The matrix which contain numerals for each 10 day period, ie 1/1-1/10 1/11-1/20

Program Data-Input

Weather Data

Archived fire weather station data for which National Fire Danger Rating System indices have been computed, are the primary inputs into the program PREFIRE. The weather data was obtained from the USDA Forest Service, Rocky Mountain Forest and Range Experiment Station. This data resides on magnetic computer tape at the Colorado State University Computer Center, and has the weather records for fire weather stations in the Black Hills for the years 1964-1973. These stations are: Nemo, Tepee, Hot Springs, Cheyenne Crossing, and Custer, South Dakota.

This raw weather data was processed via a modified version of computer program FIRDAT (Furman and Helfman, 1973) which listed the pertinent weather and the daily components and indexes of the National Fire Danger Rating System. Some output from FIRDAT was deleted and the rest copied to another magnetic tape to be used by the program FIRECOR. The data was labeled on this tape so as to facilitate easy access to any weather station and fuel type desired. This tape created from the FIRDAT data was used to compare the prescription against weather records.

Cold Front Data

The data that was input into the program FRNTPSG was obtained from weather maps and records contained in the periodicals "Weatherwise"[5/] and "Daily Weather Maps-Weekly Series"[6/]. "Weatherwise" was used for maps from January 1964 to April 1968, and from July 1969 to October 1973. "Daily Weather Maps-Weekly Series" provided maps for May 1968 to June 1969, and for November 1973 to December 1974. This data was added as a labeled file to the weather tape generated by FIRDAT. In this way the data was permanently stored for input to FRNTPSG.

TENDAYS Input

The input data into the program TENDAYS is the output from the previous two programs, PREFIRE and FRNTPSG. The first and last date of weather observa-

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[5/] Published bimonthly for the American Meteorological Society, 45 Beacon Street, Boston, Massachusetts 02108

[6/] Printed weekly by the U.S. Department of Commerce, NOAA, Environmental Data Service Public Document Department; USGPO, Washington, D.C. 20402 tions at each station each year are input to the program on cards. There is one card per year and each weather station has its own set of data cards.

Program Data - Output

PREFIRE

PREFIRE output consists of several items. First the dates which met the prescription, and the weather data and indices are listed. This list may consist of several days in a row or just one day. Following that will be the record and indices that caused a string of days to be terminated. This is immediately followed by the parameter(s) which caused that particular day to be terminated. Then the prescription is printed, along with the number of weather records read, the number of days which passed the prescription, and the percent of the days which passed. See Appendix B for sample output.

Coldfront Passage

FRNTPSG output data follows that from PREFIRE. The number of days read is printed and should equal the number of days which passed the prescription. Listed next is the number of days which were eliminated, followed by the percent of days eliminated. This format is the same for all weather stations and are listed in the same sequence as PREFIRE output. Again, see Appendix B for sample output.

TENDAYS

TENDAYS output data is presented in three tables. The first table has each year listed across the top and each 10 day period listed down the left-hand side. Printed in this table is the number of days in that period which met the prescription. Beside each number is a work, ALL, PART, or NONE. ALL indicates all ten days of the period were part of the weather record; PART indicates that only part of that period was available, while NONE indicates that not any of the days were available. If a year appears with all zeros and beside every 0 there is an "ALL" that indicates there were no days of record available for that year.

Printed below this is another table which has the years across the top, and different variables down the left-hand side. In order, these are average (ave), standard deviation (sdev), complete ten day periods, or the total number of periods in which all 10 days were recorded (CT), and the total number of days which met prescription, which fell into complete 10 day periods (SUM). These figures are output for each year. Next a table with the analysis of each 10 day period is printed. Each 10 day period is listed down the left-hand side and columns heads sum, average, and standard deviation across the top. Each 10 day period is summed over the ten years, the average is computed along with the standard deviation, and these are all printed. In computing the sum each year is added regardless of whether all or part of the 10 day period was recorded. Again, see Appendix B for example output of the program TENDAYS.

Flow of Data

In the program FIRECOR the data flows from one program to another via logical files. These files could have any 6 character name but out of convention are called TAPEn, where n is an integer from 1 to 4. This program consists of four file names or tapes. Input data that is read from cards is put on a file designated at TAPE5. In the program PREFIRE the input weather data, i.e., the data from the FIRDAT (magnetic) tape is copied to TAPE1. The output from PREFIRE is written onto TAPE2. FRNTPSG then reads from TAPE2 to check against cold front passage. The cold front data is copied from the magnetic tape to the file designated as TAPE3. Output from FRNTPSG is written onto TAPE4. TENDAYS then reads the information on TAPE4. All of the printed output is written on a file designated OUTPUT. This file is then transferred to the printer which prints out the data on paper. All of the input data for each of the 3 programs that is read from cards, is placed on a file named TAPE5.

Job Terminators

There are three built-in job terminators in the program PREFIRE which cause the run to terminate in case of an error. This prevents costly computer time. The first of these will terminate the job if an end-of-file (EOF) is encountered on TAPE5, the card input. A message will be printed stating *RAN OUT OF INPUT CARDS TOO SOON*, and the job will be stopped. The second job terminator occurs if N (the number of variables or prescription parameters) is greater than 20. A message is printed letting the user know that he has used more than 20 variables or has made a key punching error. Thirdly, if the constraint number read from a parameter card is less than 1 or the number of constraints are greater than N then the job will be stopped. The message than an illegal value has been used is printed.

Print Flags

There is one print flag in the program PREFIRE. The variable IPRF is used. If it is equal to 1 then printing of the days that passed the prescription will be suppressed. The printing of string of days termination information will also be suppressed. These print flags may be used to suppress printing in order to save output costs.

Chapter 5. Results and Discussion

The main objective of this research was to find the frequency of favorable burning conditions in the Black Hills. The results are presented in this chapter, followed by a discussion for each of the main burning objectives and/or fuel model types.

Initial Prescriptions

The initial prescriptions recommended for each fuel type were discussed in Table 4 (Chapter 3) and are repeated in Table 8. Each of these prescriptions was used as input into the computer program FIRECOR to compute the frequency of satisfactory burning days. The results are shown in Table 8. The initial prescriptions for both ponderosa pine thinning slash and timber litter were met less than one day per year at each of the five weather stations. We conclude that a significant burning program is not possible in the Black Hills National Forest in these two fuels unless one or more of the prescription variables are relaxed. On the other hand, burning of grasslands would have been possible at the Nemo and Tepee stations on 11 days per year and at Hot Springs on 16 days per year.

The initial prescriptions were revised to find a range of prescribed weather values that would allow a significant number of burning days in each fuel type. It will be shown in the following pages that a slight relaxation of certain burning restrictions would greatly increase the number of days available for burning.

Table 8. Frequency of days that the initial burning prescription was met at mid-day at fire weather stations in the Black Hills.

Fuel Model A (Grassland)

	Nemo	Tepee	Hot Springs
total # days passed	88	115	145
total # records checked	1699	1934	2018
% days passed	5.18	5.95	7.19
ave # days/yr.	11	11.3	16.11

Initial Prescription

BI	0-12
TEMP	70°-90°F
RH	10-25%
WS	5-12 MPH
1HRFM	0-12%

Table 8. (Continued)

Fuel Model C (Thinning Slash)

	Chey. Cross.	Nemo	Custer	Tepee	Hot Springs
total # days passed	0	2	6	1	4
total # days checked	1526	1699	1947	1934	2018
% days passed	0	0.12	0.10	0.05	0.049
Ave. # days/yr.	0	0.20	0.67	0.10	0.44

Initial Prescription

BI	0-30
TEMP	65°-85°F
RH	10-25%
WS	5-10 MPH
1HRFM	10-25%
10HRFM	10-30%

Fuel Model E (Ponderosa pine litter)

	Nemo	Tepee	Hot Springs
total # days passed	0	0	0
total # days checked	1786	1934	2018
% days passed	0	0	0
ave # days/yr.	0	0	0

Initial Prescription

BI	0-25
TEMP	70°-80°F
RH	20-30%
WS	3-8 MPH
1HRFM	15-25%
10HRFM	15-20%

Prescribed Burning Weather

The objective of this research study was to determine frequency of favorable burning conditions for prescribed fire. The weather records of five stations, in the Black Hills, for 10 years were used as a basis for the study. Fuel models were used to characterize and standardize the fuels present in and around these weather stations. The results of this research are presented below for each fuel model used, or for each burning objective.

Pine Invasion of Grassland

When pine seedlings are invading a grassland meadow, it may be desireable to use prescribed fire in order to eliminate the seedlings. Therefore a high intensity fire, of long duration is needed to insure greatest tree mortality. High intensity fires can be obtained by burning under the right conditions, these being generally low fuel moistures, and low wind speeds. Figure 5 represents fire behavior as modeled using Rothermel's (1972) mathematical fire spread model. Figure 5a shows rate-of-spread as related to fuel moisture and surface wind velocity. A range of rates of spread can be found between 2 and 12 MPH, and a fuel moisture of 5%. This would give a rate of spread between 50-100 ft/min. Figure 5b shows the relationship between fuel moisture and reaction intensity. For example, a fuel moisture of 5% should result in a reaction intensity of

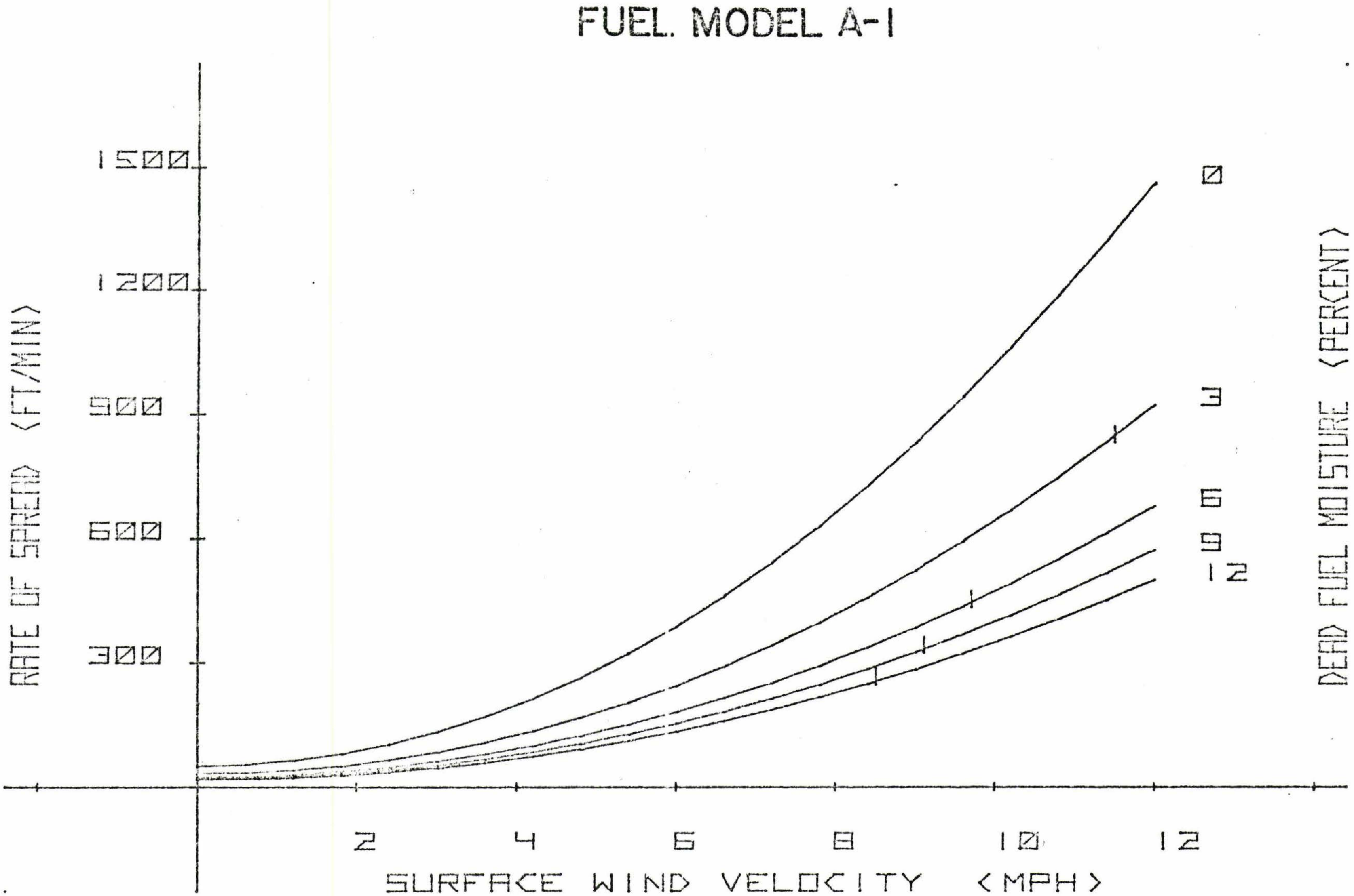

FIGURE 5a. Graph for Fuel Model A, prescription I, showing Rate of Spread as related to surface wind velocity and fuel moisture.

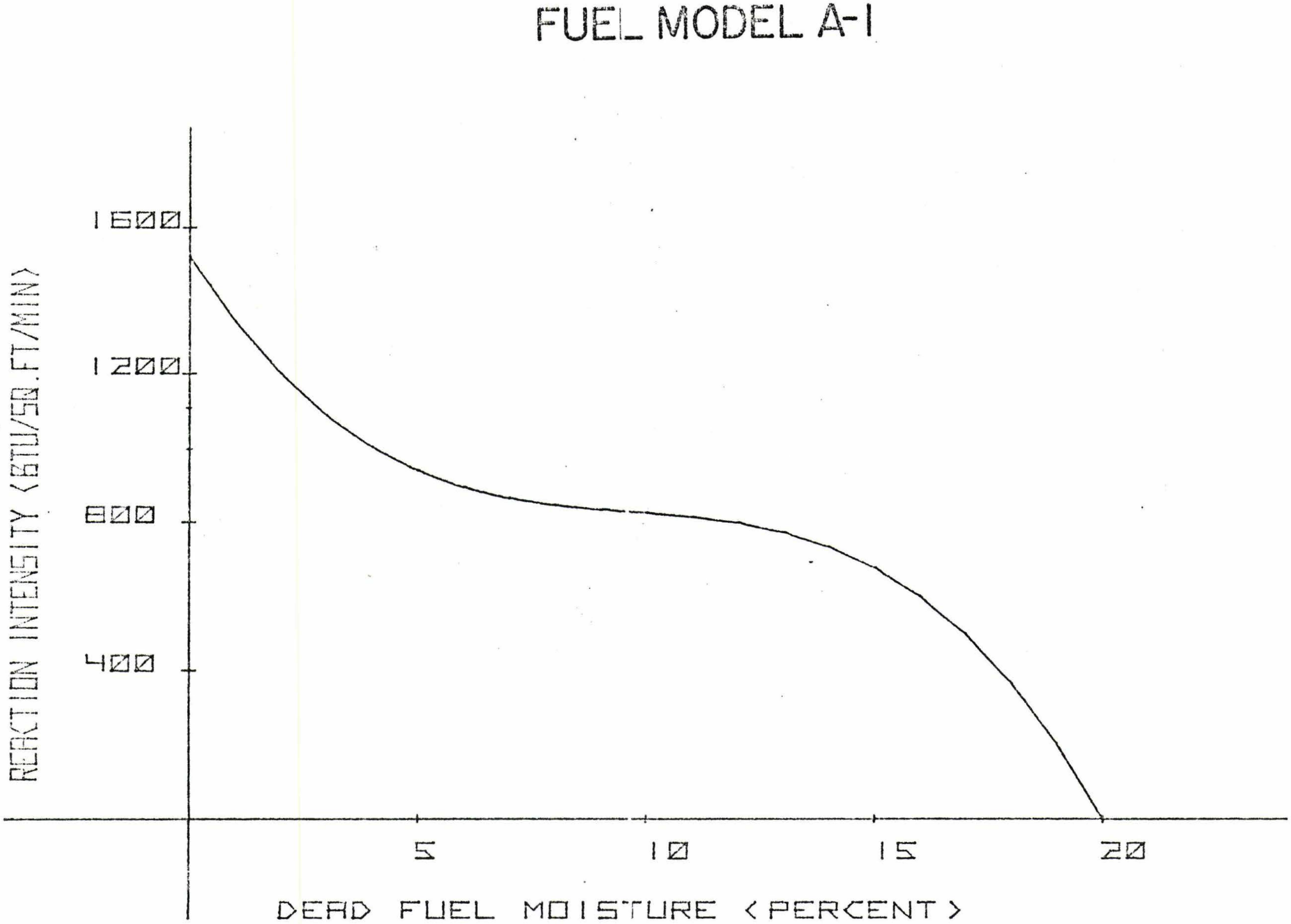

FIGURE 5b. Graph for Fuel Model A, prescription I, showing Reaction Intensity as related to dead fuel moisture.

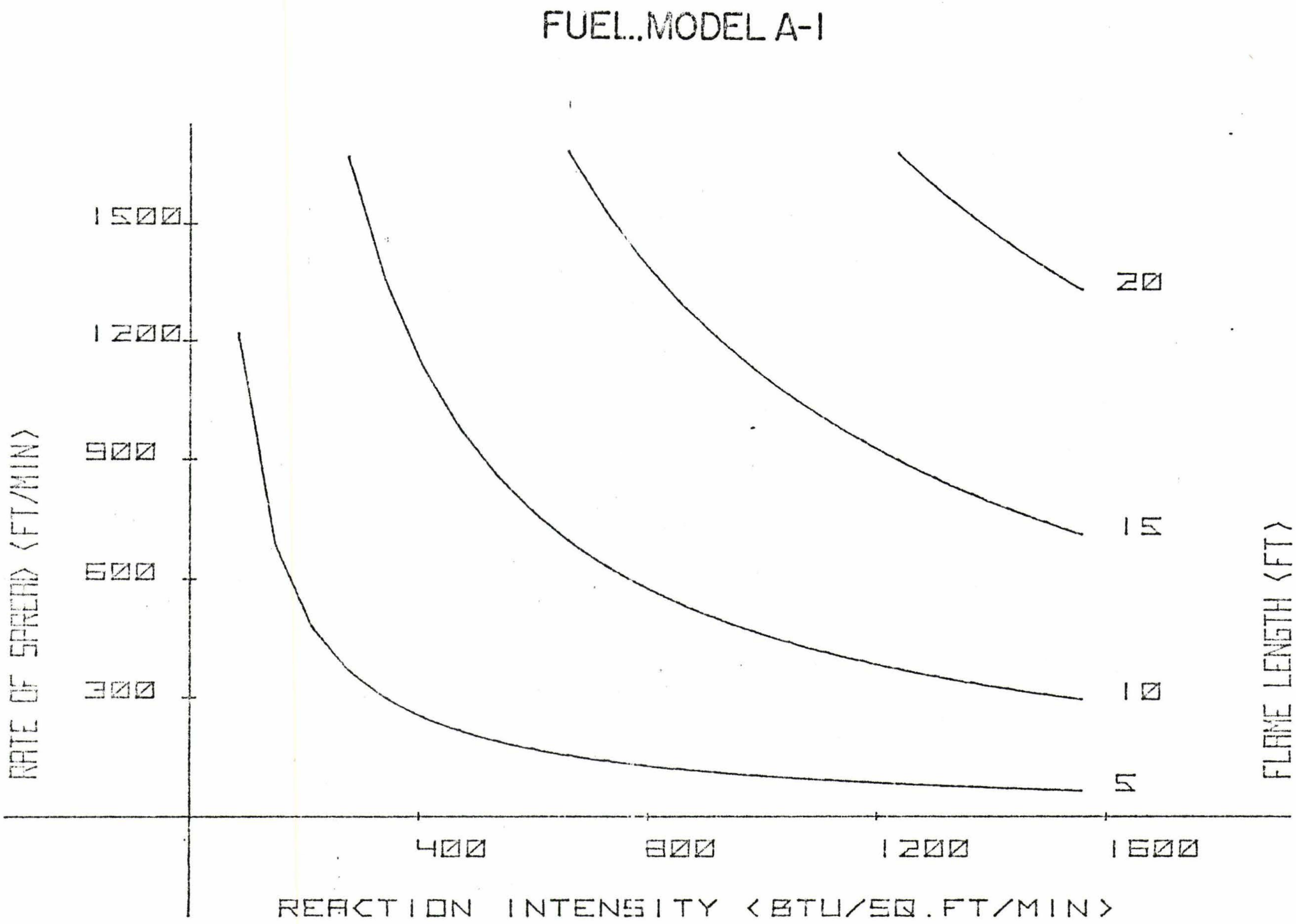

FIGURE 5c. Graph for Fuel Model A, prescription I, showing Flame Length as related to rate of spread and reaction intensity.

about 950 BTU/ft^2/min. Figure 5C shows flame lengths as related to rate of spread and reaction intensity. Several combinations of rate of spread and intensity could give the same flame length. In the example, an intensity of 950 BTU/ft^2/min., and a rate of spread of 100 ft/min. gives an approximate flame length of 5 feet.

The conditions that are recommended for burning are set in a burning prescription. The initial prescription used to determine the frequency of favorable conditions has been presented in Table 4 and Table 8. The days which met the prescription are presented in Figure 6 and summarized in Table 9. Figure 6 is a graphical display of the number of days which met the prescription in each 10 day period for the entire 10 years. Appendix C contains graphs for each prescription in each fuel model for each weather station. In the initial prescription, Hot Springs had a total of 145 days or 14.5 days per year while Tepee has 115 or 11.5 days per year, and Nemo 88 or 8.8 days per year.[1/] September had the most days in which the prescription was met at both Hot Springs and Nemo. August was the best month at Tepee. The best 10 day period was August 19 to August 28 for both Hot Springs and Tepee, with 15 and 16 days respectively, Nemo had 14 days in the period September 28 to October 7. The high air temperature in the prescription might account for the best 10 day periods being in August.

Examination of the computer output revealed that the most limiting parameters were air temperature and relative humidity. When temperature parameter was relaxed from 70° to 65° there was an 18% , 8% and 14% increase in the number of burning days for Nemo, Tepee and Hot Springs respectively.

From the data presented in Table 9, and an examination of the graphs in Appendix C, it appears that for Fuel Model A, Nemo Station area, the 10 day period of September 28 to October 7 has had the highest number of days meeting the prescription. The month of September also seems to be a month in which favorable burning conditions are likely to occur. In the Tepee weather station area the 10 day period September 28 to October 7 again is the period most likely to have favorable days for burning. The month of August seems to be a month which would also allow burning to be done. The Hot Springs weather station

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[1/] Averaged over 10 years.

Table 9. Summary of prescription data for Fuel Model A (Grasslands); each weather station, for prescription 1, 2, and 4; and the days of record that met the prescription in the period 1964-1973.

NEMO A		1	2	4
Prescription:	TEMP	70-90°	65-90°	65-80°
	RH	10-25%	10-25%	10-30%
	WS	5-12MPH	5-12MPH	5-12MPH
	1 HRFM	0-12%	0-12%	0-12%
	BI	0-12	0-12	0-12
Total # of days satisfactory		88	107	96
% of days		5.18	6.30	5.65
Ave. # days/yr		11	11.89	10.67
Best month		Sept.	Sept.	Oct.
# days/yr in best month		2.5	2.6	3.0
Best 10 day period		9/28- 10/7	9/28- 10/7	9/28 10/7
# days/yr in best 10 day period		1.4	1.7	2.1

Tepee A		1	2	4
Prescription:	TEMP	70-90°	65-90°	65-80°
	RH	10-25%	10-25%	10-30%
	WS	5-12MPH	5-12MPH	5-12MPH
	1 HRFM	0-12%	0-12%	0-12%
Total # of days satisfactory		115	125	113
% of days		5.95	6.46	5.84
Ave. # days/yr		11.30	12.30	11.30
Best month		Aug.	Aug.	Sept.
# days/yr in best month		3.9	3.5	2.4
Best 10 day period		8/19- 8/28	8/19- 8/28	9/28- 10/7
#days/yr in best 10 day period		1.6	1.6	1.8

Hot Springs A		1	2	4
Prescription:	TEMP	70-90°	65-90°	65-80°
	RH	10-25%	10-25%	10-30%
	WS	5-12MPH	5-12MPH	5-12MPH
	1 HRFM	0-12%	0-12%	0-12%
	BI	0-12	0-12	0-12
Total # days satisfactory		145	169	133
% of days		7.19	8.37	6.59
Ave # days/yr		16.11	18.78	14.56
Best month		Sept.	Sept.	Oct.
# days/yr in best month		3.4	3.8	3.7
Best 10 day period		8/19- 8/28	9/28- 10/7	9/28- 10/7
# days/yr in best 10 day period		1.5	1.6	2.1

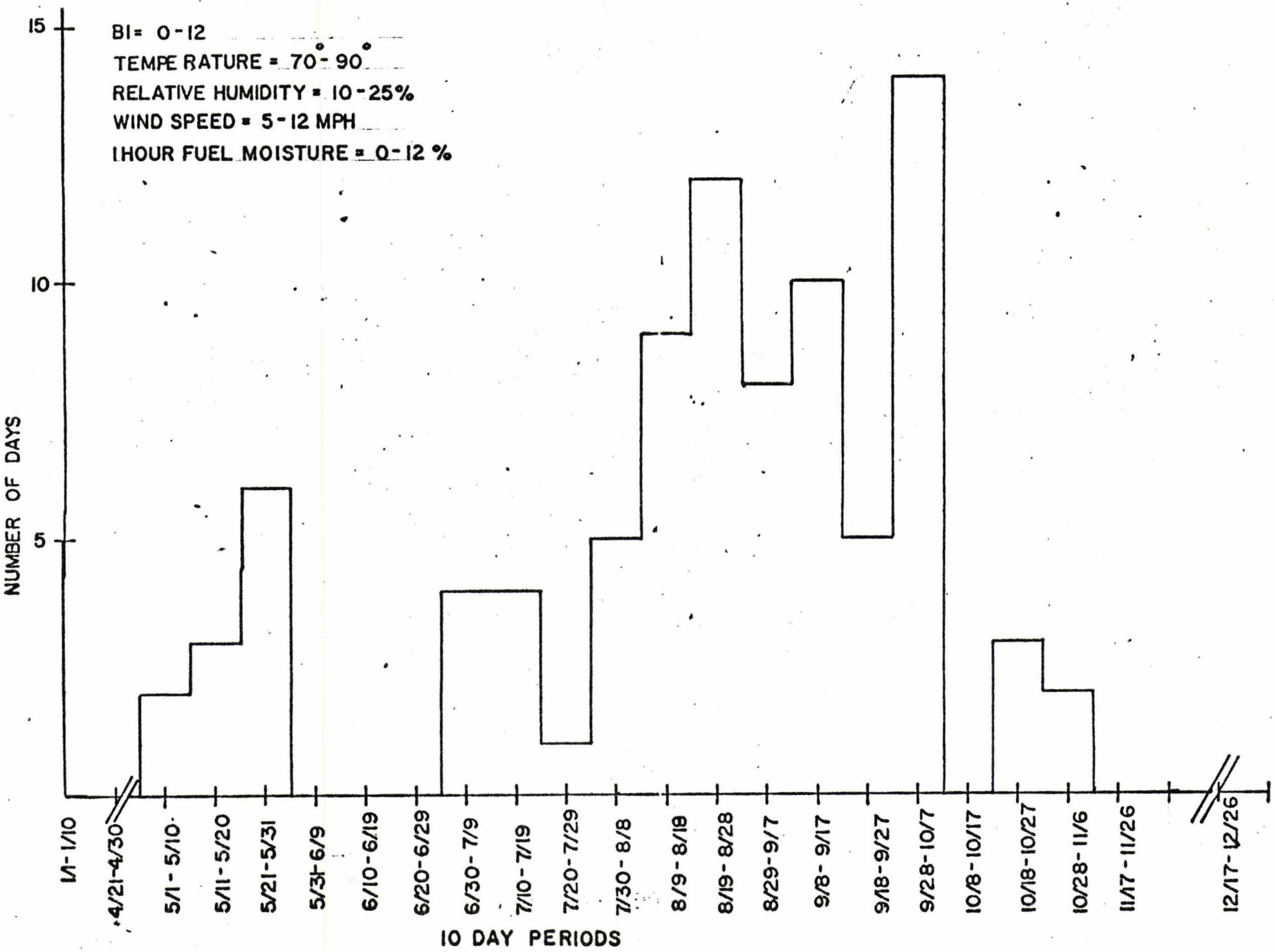

Figure 6a. Ten days data for Nemo Station, fuel model A, prescription #1. Graph shows total number of days for each 10 day period, which met the given prescription, over the entire 10 year period.

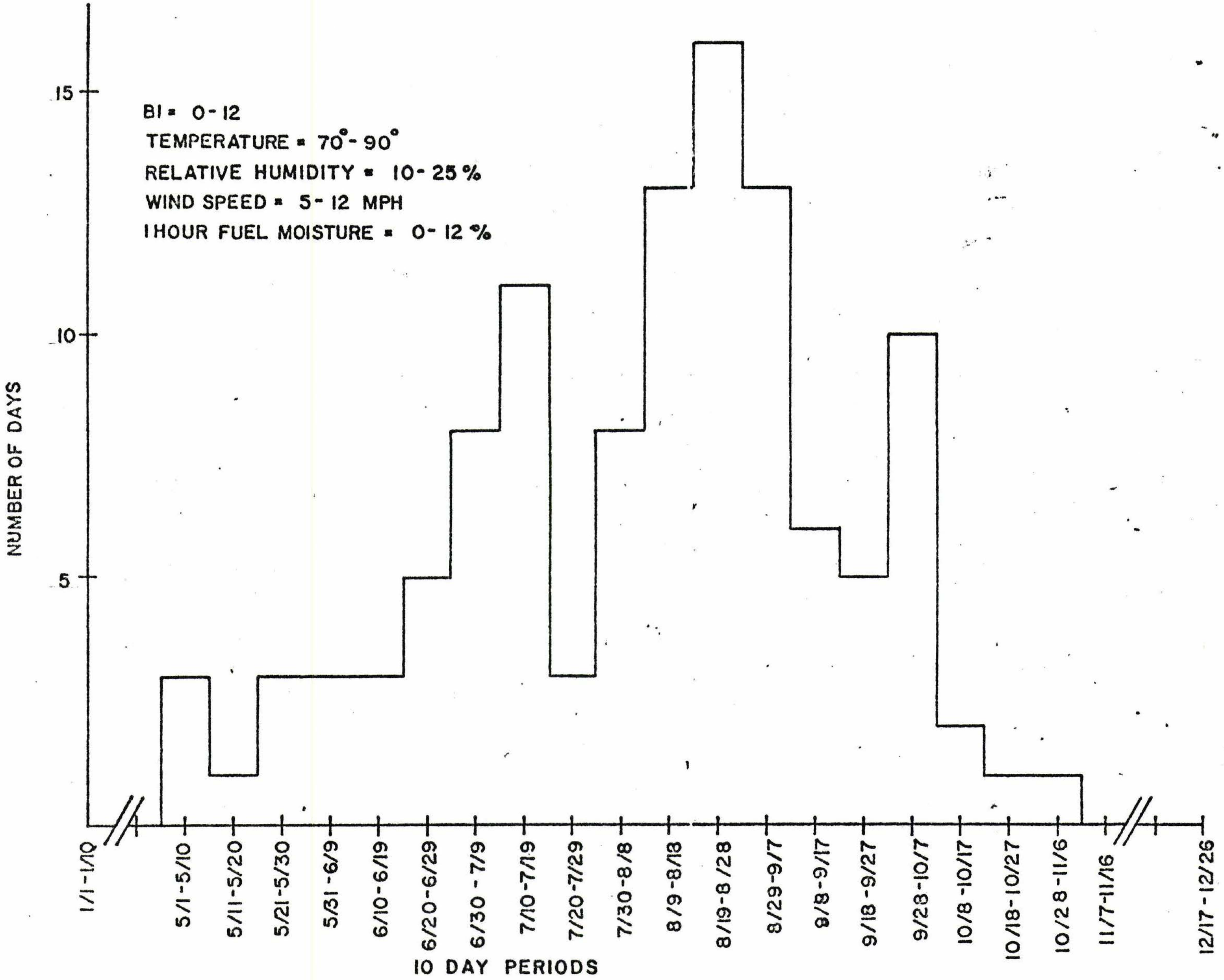

Figure 6b. Ten days data for Tepee Station, fuel model A, prescription #1. Graph shows total number of days for each 10 day period, which met the given prescription, over the entire 10 year period.

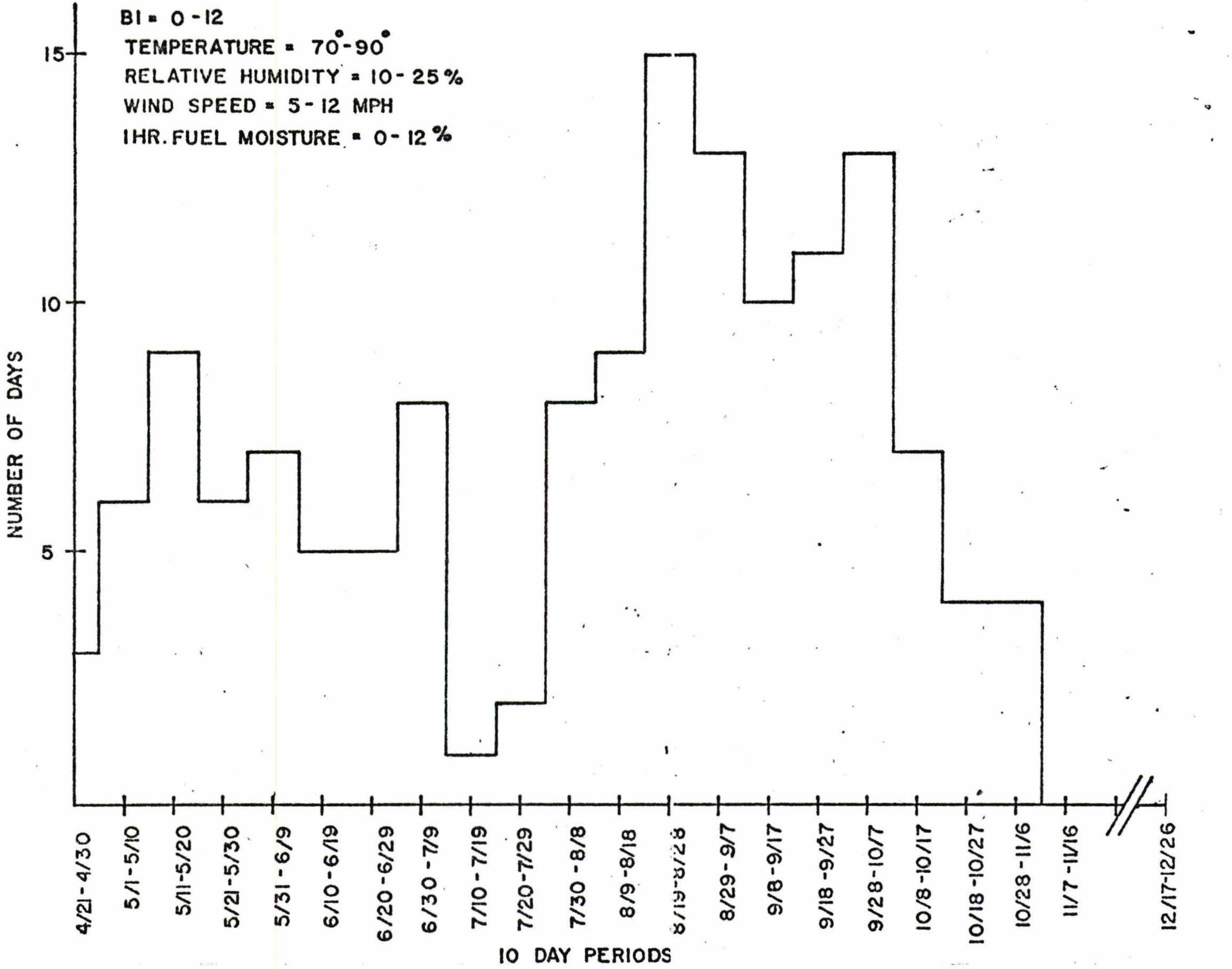

Figure 6c. Ten days data for Hot Springs Station, fuel model A, prescription #1. Graph shows total number of days for each 10 day period, which met the given prescription, over the entire 10 year period.

area has also had the most favorable conditions in the 10 day period September 28 to October 7. The periods October 8 to October 17, and October 18 to October 27 have also had favorable days, while September and October seem to be the best months. The certainty of days meeting a prescription in these 10 day periods is fairly high, as these 10 day periods continuously had the most days throughout the 10 year period studied. An average of 19 days per year has met the prescription on the forest as a whole.

Fire Used to Reduce Hazard

Logging or thinning slash, when left untreated, can be a fire hazard. To reduce this hazard the fuel must be treated, and the use of fire is one method of treatment. The fire must spread in the slash, but of low intensity or short duration to minimize tree mortality.

Figure 7 shows the graphs for the fire behavior of prescription 1 for slash fuel model. These graphs and those in the appendix give an idea of the intensities obtained over the range of prescription values given. The initial prescription for the slash fuel model yielded few days if any at each weather Station during the ten year period. Cheyenne Crossing had no days, Nemo had 2, Tepee had 1, Custer 6, and Hot Springs 4. This data is summarized in Table 10. The ten hour time-lag fuel moisture was the parameter most limiting, and when its range of values were increased the number of days meeting the prescription was greatly increased. The increase in total days for the ten year period was 0 to 153 which is 15.3 days/yr at Cheyenne Crossing, 2 to 232 (23.2 days/yr) at Nemo, 6 to 295 (29.5 days/yr) at Custer, 1 to 272 (27.2 days/yr) at Tepee, and 4 to 286 (28.6 day/yr) at Hot Springs. From the graphs in Appendix C it appears that relaxing 1 hr. fuel moisture had very little, if any real effect on the total number of days.

Prescription #3 gave the highest total days which met the prescription, but most of these days occurred in the summer months, due to the high temperature values and low fuel moistures. In this prescription July or August was the best month in all cases. Prescription #4 gave the best results because at all weather stations except Cheyenne Crossing, October was the best month, and October 18 to October 27 was the best ten day period, except at Hot Springs where October 8 to October 17 was the best 10 day period.

An interesting observation can be made by examining the fuel moistures expecially the ten hour fuel moistures for prescriptions #4, #10, and #13 (See graphs, Appendix C). In these three prescriptions the only variables that change are the fuel moistures. The number of days decreases slightly as the moisture values decrease. It would appear that with the other variables being equal that the largest percent of fuel moisture range between 5% to 10% or 15%. This is taken over an entire ten year period. While in some years fuel moistures may be higher it appears that over the entire period the fuel moistures maintain the relatively low values.

Prospects for a burning program seem to be good in this fuel model also. From Table 10 it appears that October again is the best month in which to burn but the graphs also show that in May some burning could take place. The best ten day period is October 18 to October 27, and the springtime period is May 11 to May 20. It is fairly certain that days will occur during these periods, but the numbers may be low.

Table 10. Summary of prescription data for fuel Model C, thinning slash; each weather station, prescription 1, 3, and 13; and the frequency of days meeting the prescription. Data is summed over the entire 10 year period.

Cheyenne Crossing

Prescription	1	3	13
TEMP	65-85°	65-85°	40-65°
RH	15-50°	15-50%	15-40%
WS	5-10MPH	5-10MPH	5-10MPH
1 HRFM	10-25%	5-30%	5-10%
10 HRFM	10-30%	5-130%	5-10%
BI	0-30	0-30	0-30
Total # days	0	153	88
% days	0	10.03	5.77
Ave # days/yr	0	18.88	17
Best month	--	July	May
# days/yr in best month	0	4.5	2.7
Best 10 day period	--	7/10-7/19	5/11-5/20
# days/yr in best 10 day period	0	1.7	1.4

Hot Springs

Prescription	1	3	13
TEMP	65-85°	65-85°	40-85°
RH	15-50%	15-50%	15-40%
WS	5-10MPH	5-10MPH	5-10MPH
1 HRFM	10-25%	5-30%	5-10%
10 HRFM	10-30%	5-30%	5-10%
BI	0-30	0-30	0-30
Total # days	4	286	146
% days	.020	14.17	7.23
Ave # days/yr	.44	31.78	20.33
Best month	--	Aug.	Oct.
# days/yr in best month	0	6.6	2.7
Best 10 day	5/31-6/9 6/10-6/19 8/19-8/28 9/8-9/17	7/20-7/29	10/8-10/17
# days/yr in best 10 day period	0.1	2.6	1.3

Table 10. (Continued)

Custer

Prescription	1	3	13
BI	0-30	0-30	0-30
RH	15-50%	15-50%	15-40%
WS	5-10MPH	5-10MPH	5-10MPH
1 HRFM	10-25%	5-30%	5-10%
10 HRFM	10-30%	5-30%	5-10%
Total # days satisfactory	6	295	144
% days	.031	15.15	7.40
Ave # days/yr	.67	29.5	22.89
Best month	Aug.	Aug.	Oct.
# days/yr in best month	0.3	7.7	4.1
Best 10 day period	7/30- 8/8	7/10- 7/19	10/18- 10/27
# days/yr in best 10 day period	0.2	3.0	2.4

Nemo

Prescription	1	3	13
BI	0-30	0-30	0-30
RH	15-50%	15-50%	15-40%
WS	5-10MPH	5-10MPH	5-10MPH
1 HRFM	10-25%	5-30%	5-10%
10 HRFM	10-30%	5-30%	5-10%
Total # days satisfactory	2	232	96
% days	.012	13.66	5.65
Ave # days/yr	.22	25.67	14.56
Best month	Aug.	Aug.	Oct.
# days/yr in best month	0.2	6.1	4.2
Best 10 day period	7/30 8/8	8/19 8/28	10/18 10/27
# days/yr in best 10 day period	0.2	2.3	2.0

Tepee

Prescription	1	3	13
BI	0-30	0-30	0-30
TEMP	65-85°	65-85°	40-65°
RH	15-50%	15-50%	15-40%
WS	5-10 MPH	5-10 MPH	5-10 MPH
1 HRFM	10-25%	5-30%	5-10%
10 HRFM	10-30%	5-30%	5-10%
Total # days satisfactory	1	272	120
% days	.005	14.06	6.20
Ave # days/yr	.10	27.2	15.4
Best month	May	July	Oct.
# days/yr in best month	0.1	6.5	4.3
Best 10 day period	5/21- 5/30	6/30- 7/9	10/18- 10/27
# days/yr in best 10 day period	0.1	3.0	1.9

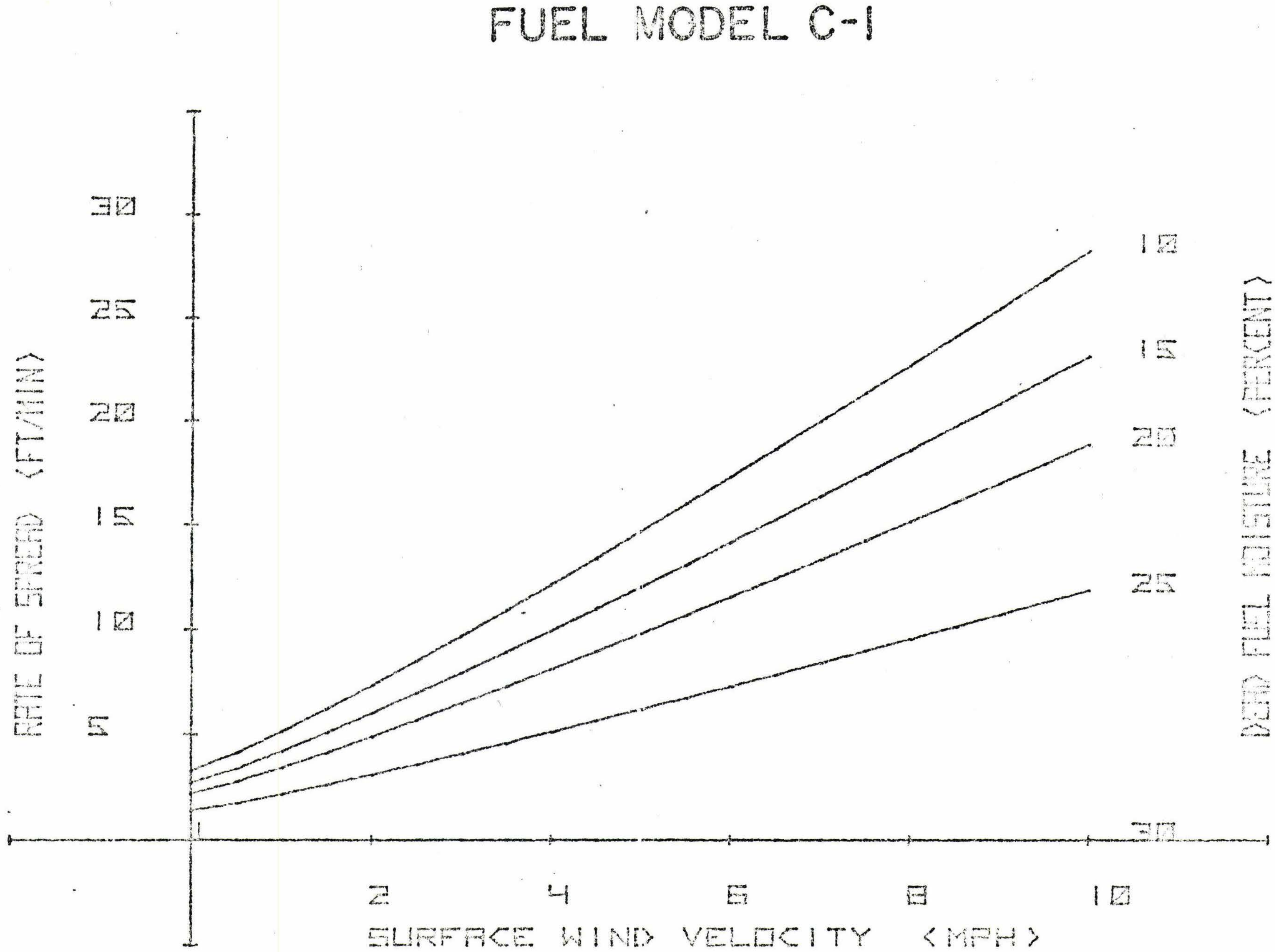

FIGURE 7a. Rate of spread graph for Fuel Model C, prescription I.

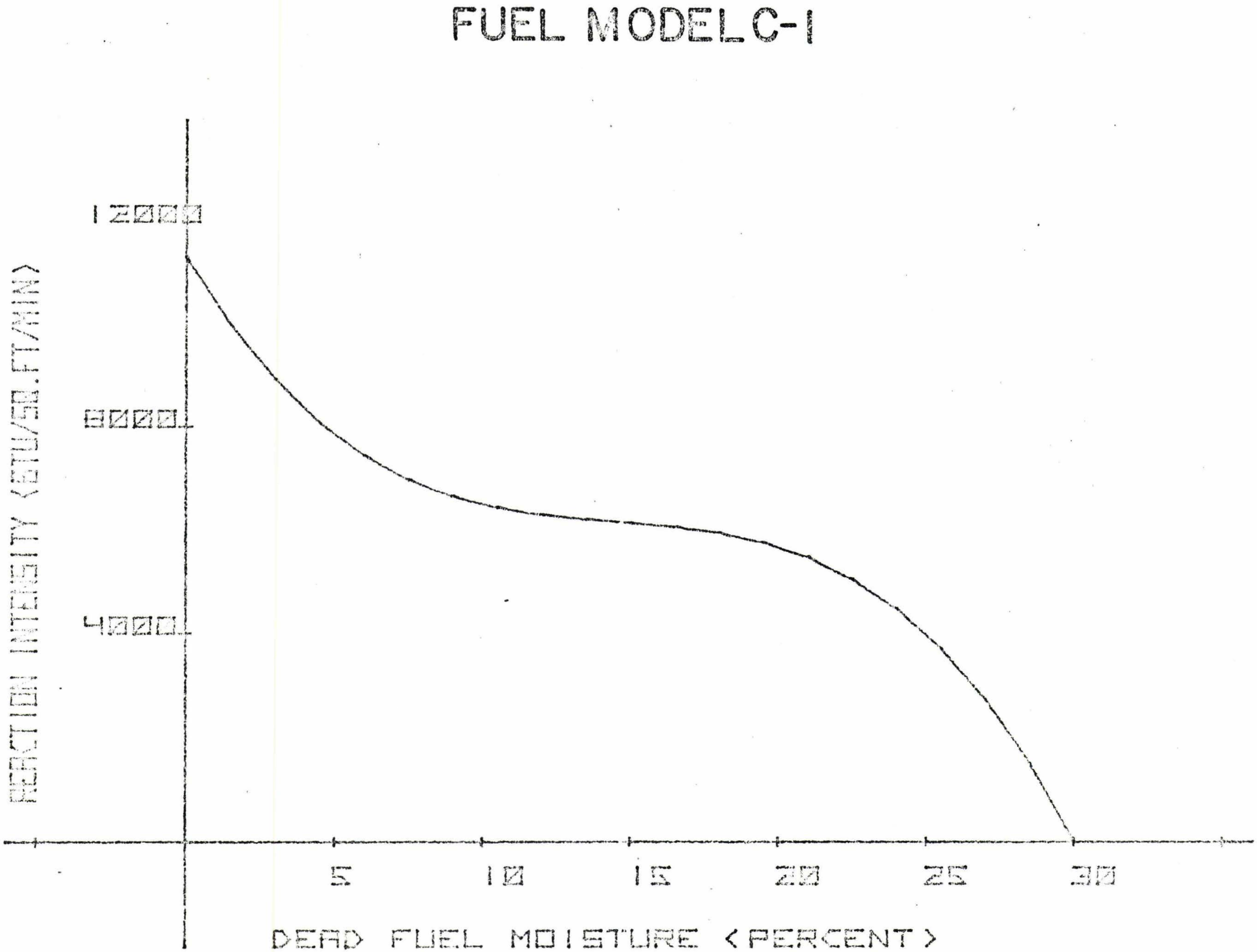

FIGURE 7b. Reaction intensity graph for Fuel Model C, prescription I.

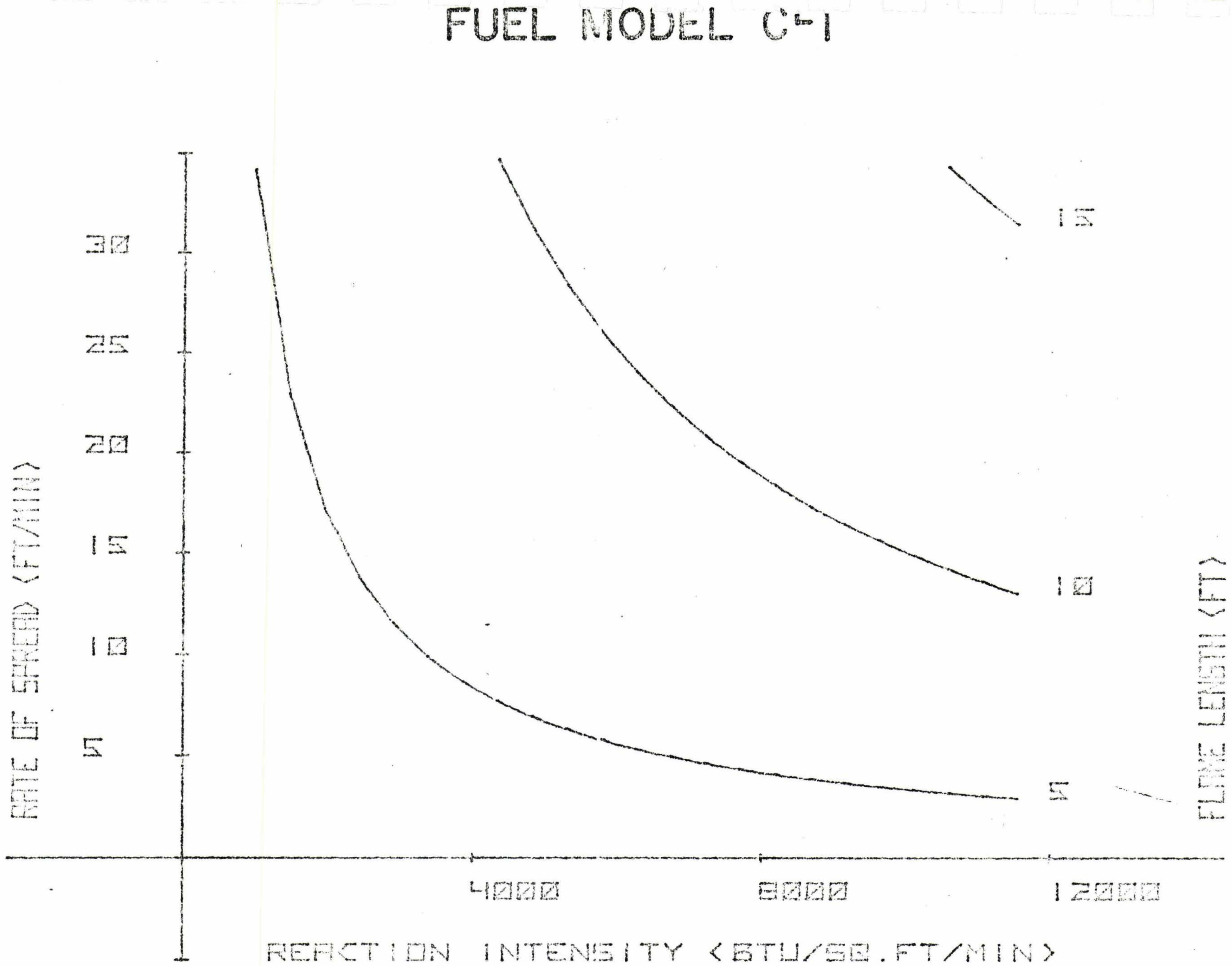

FIGURE 7c. Flame length graph, Fuel Model C, prescription I.

Overstocked or Closed Canopy

The purpose of using fire in this fuel type is as a thinning agent. Cambium heating and crown scorch are ways in which smaller and/or suppressed trees might be killed. This would call for a fire of moderate intensity with low wind speed. Low wind is necessary so that the heat will not be dispersed as rapidly and will remain to cause mortality and crown scorch. Figure 8 shows the behavior graphs for prescription #1. Again these graphs will tell what fire behavior can be expected from a range of values for wind velocity and fuel moisture.

The initial prescription for each weather station with this fuel type did not yield a single day, as seen in Table 11. Fuel moisture, especially 10 hour timelag fuel moisture, appeared to be the limiting factor. After the initial run, four more prescriptions were run varying temperature, relative humidity and 1 hour time lag fuel moisture. Finally prescription 6, where 10 hour time lag fuel moisture was relaxed, favorable days were obtained for each station. At Nemo the increase was from 0 days to 167 total days (16.7 days/yr), 0 to 256 days (25.6 days/yr) at Tepee, and 0 to 227 (22.7 days/yr) at Hot Springs. Figure 9 shows the graph for Nemo #6, and Appendix C has graphs for other prescriptions. Prescriptions 6 and 7 give high values, but most of the days fall in the summer time when fire danger is high. Prescription #11 has fewer total days, but most of the days are in the spring and fall. At each weather station the best month is October and the best 10 day period is October 18 to October 27 except at Hot Springs where the best period is November 17 to November 26, for prescription #11.

With this fuel model, an examination of Table 11 will reveal again that most of the fuel moistures lie between 5% and 10% or 15% over the entire 10 year period. Again, the moistures don't always fall within this range each day, but the majority of the days examined fell within it. Usually fuel moisture is most influenced by relative humitity in this fuel model, as well as the other.

The prospects for a burning program look good in this fuel model also. Again looking at Table 11 and the graphs in the appendix it would seem that the best time to burn would be in October and/or the 10 day period of October 18 to October 27 as this period had the most days over the 10 years then it would appear that in planning to burn during this period there is reasonable certainty that favorable conditions would occur. May might also be a good month in which to burn. The 10 day period with the highest certainty of favorable conditions occuring is May 11 to May 20.

FUEL MODEL E-II

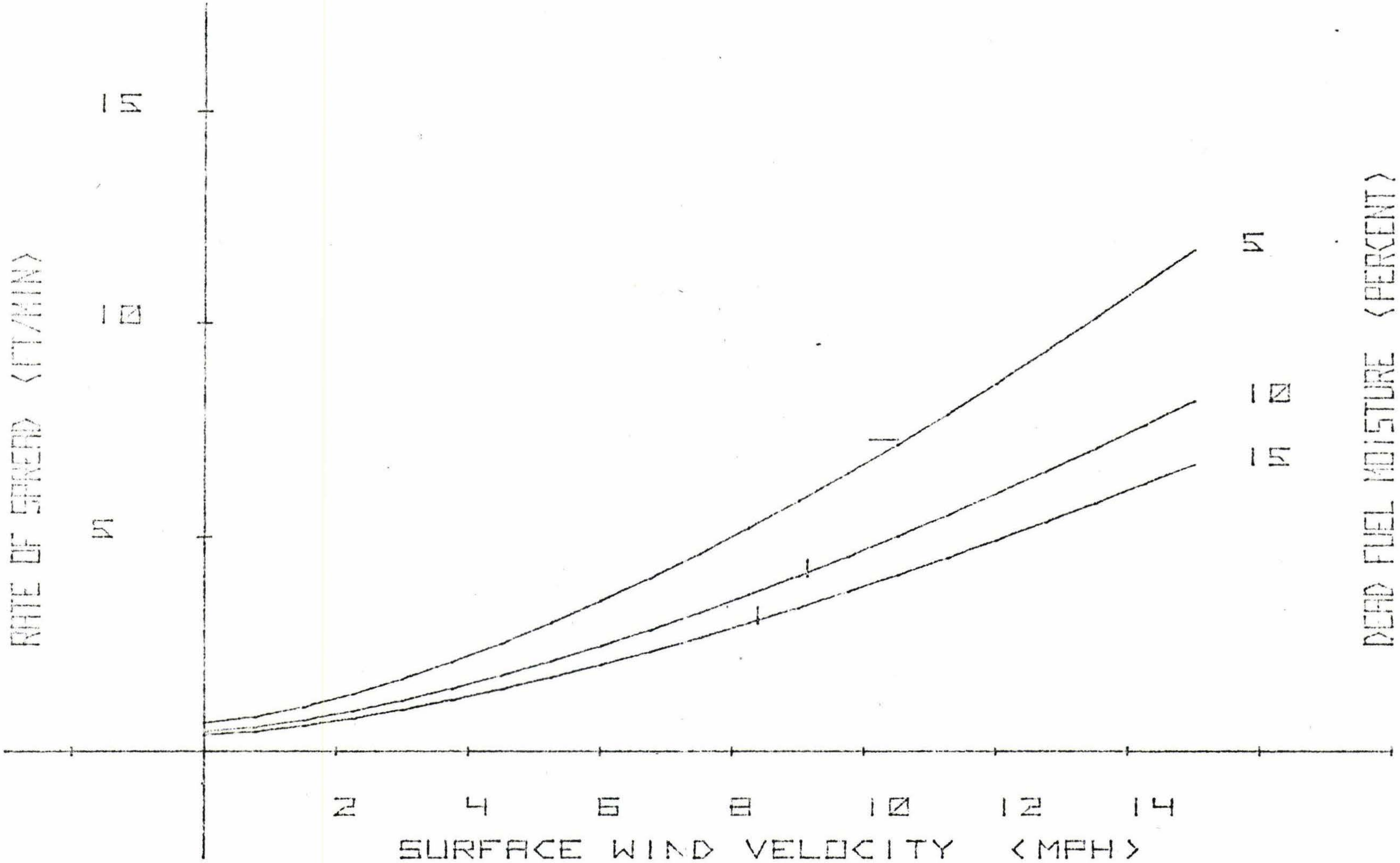

FIGURE 8a. Rate of spread graph for Fuel Model E, prescription II

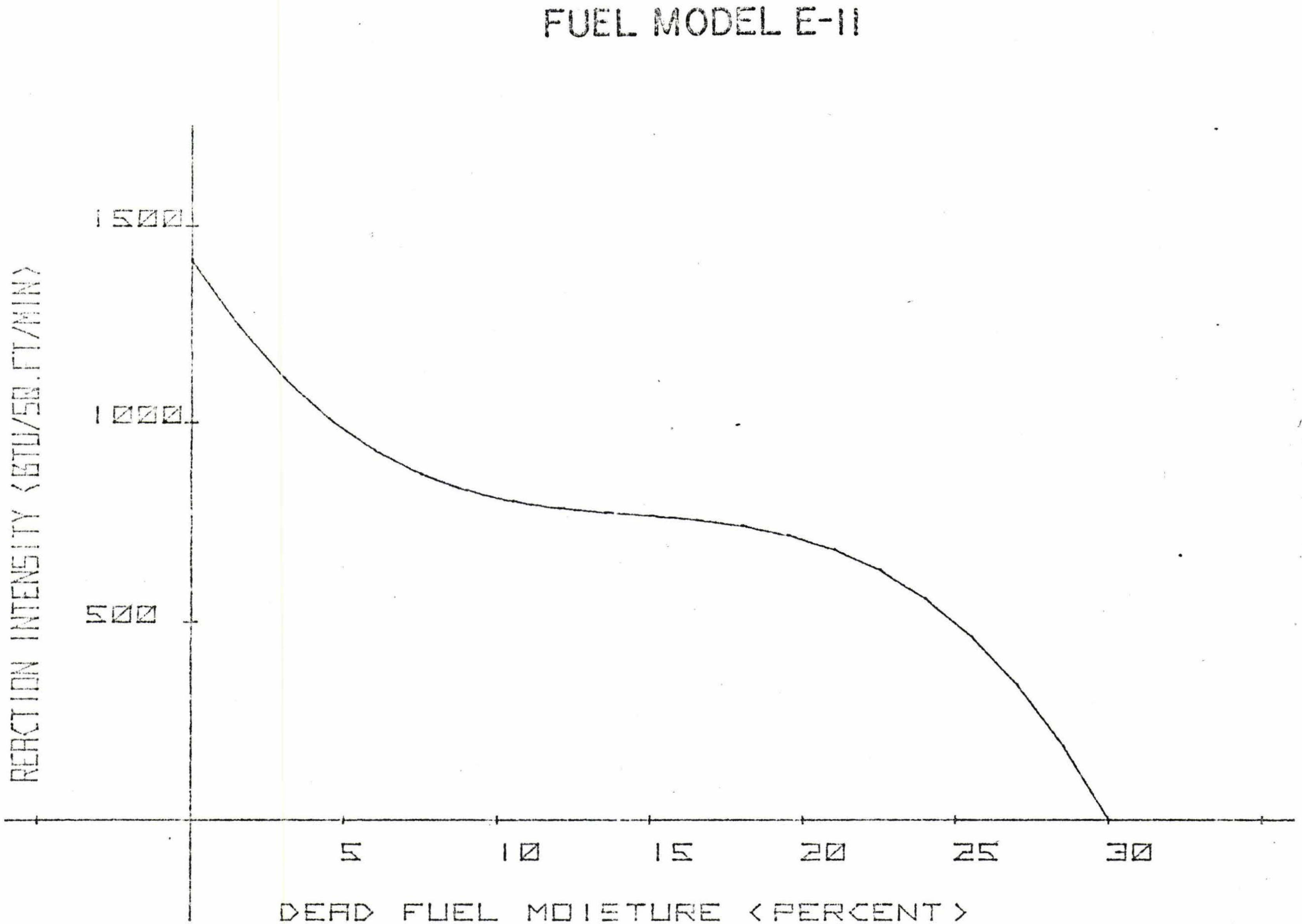

FIGURE 8b. Reaction intensity graph for Fuel Model E, prescription II

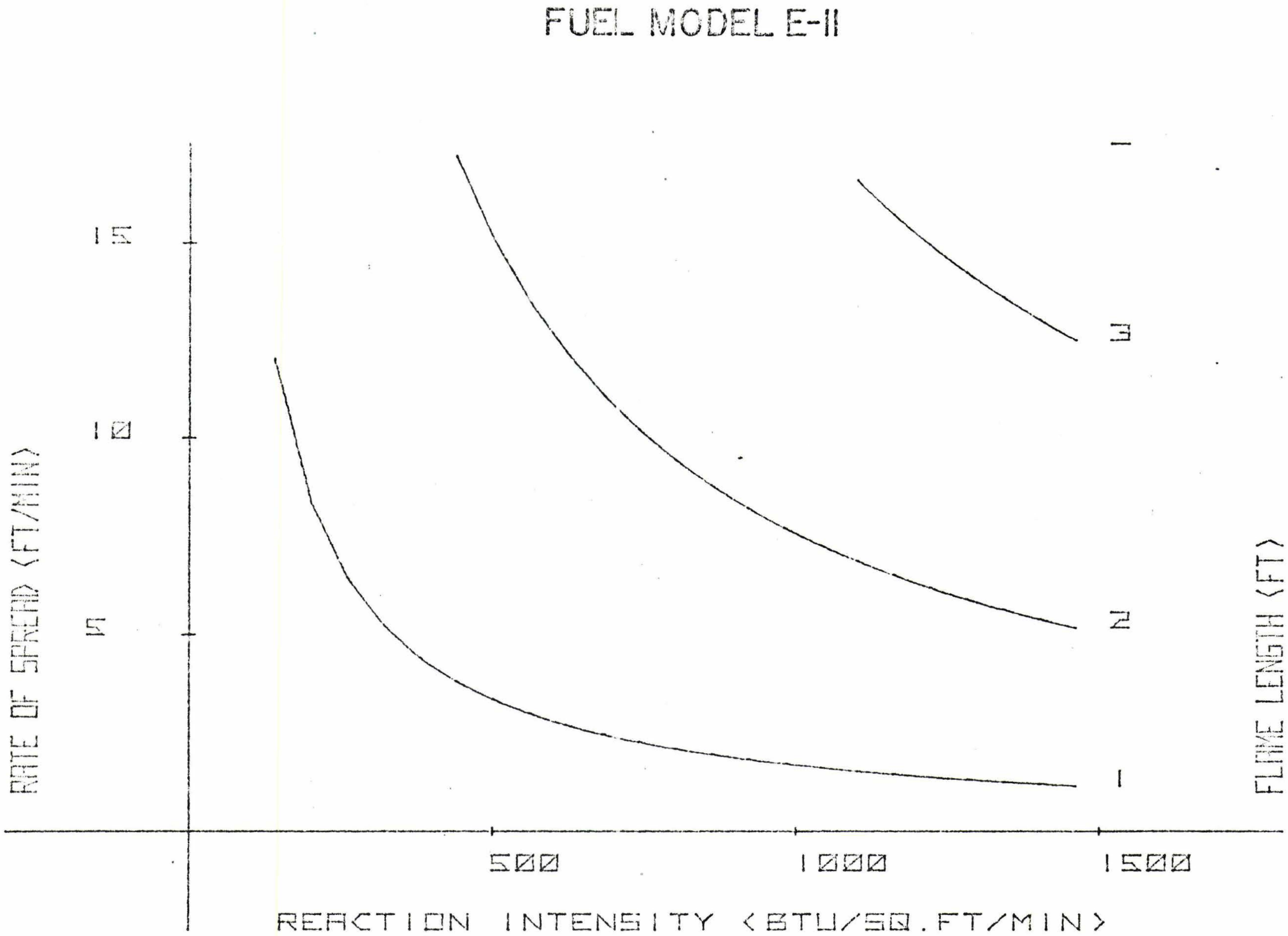

FIGURE 8c. Flame length graph for Fuel Model E, prescription II

Table 11. Summary table of prescriptions and results for 3 stations, Fuel Model E, timber litter, and the frequency of days meeting the prescription. Summed over the entire 10 year period.

Nemo E

Prescription	1	6	7	11
BI	0-25	0-25	0-25	0-25
TEMP	70-80°	60-90°	60-90°	40-65°
RH	20-30%	15-40%	15-40%	15-40%
WS	3-8MPH	3-8MPH	5-15MPH	5-15MPH
1 HRFM	15-25%	5-25%	5-25%	5-15%
10 HRFM	15-20%	5-20%	5-20%	5-15%
Total # days satisfactory	0	167	276	101
% of days	0	9.35	15.45	5.66
Ave # days/yr	0	16.22	27.30	9.30
Best month	--	Aug	Aug	Oct
# days/yr in best month	0	3.9	7.6	1.8
Best 10 day period	--	8/19-8/28	8/19-8/28	10/18-10/27
# days/yr in best 10 day period	0	1.7	3.1	1.9

Tepee E

Prescription	1	6	7	11
BI	0-25	0-25	0-25	0-25
TEMP	70-80°	60-90°	60-90°	40-65°
RH	20-30%	15-40%	15-40%	15-40%
WS	3-8MPH	3-8MPH	5-15MPH	5-15MPH
1 HRFM	15-25%	5-25%	5-25%	5-15%
10 HRFM	15-20%	5-20%	5-20%	5-15%
Total # days satisfactory	0	256	314	125
% of days	0	13.24	16.24	6.46
Ave # days/yr	0	25.40	31.30	11.60
Best month	--	Aug	Aug	Sept-Oct
# days/yr in best month	0	6.5	7.2	1.6
Best 10 day period	--	8/19-8/28	8/19-8/28 8/29-9/7	10/18-10/27
# days/yr in best 10 day period	0	2.7	2.8	1.7

Table 11. (Continued)

Hot Springs E

Prescription:	1	6	7	11
BI	0-25	0-25	0-25	0-25
TEMP	70-80°	60-90°	60-90°	40-65°
RH	20-30%	15-40%	15-40%	15-40%
WS	3-8MPH	3-8MPH	5-15MPH	5-15MPH
1 HRFM	15-25%	5-25%	5-25%	5-15%
10 HRFM	15-20%	5-20%	5-20%	5-15%
Total # days satisfactory	0	227	327	173
% of days	0	11.25	16.20	8.57
Ave # days/ yr	0	25.11	35.33	19
Best month	--	Aug	Aug	Oct
# days/yr in best month	0	5.1	6.5	1.0
Best ten day period	— —	7/30- 8/8	7/30-8/8 8/29-9/7	11/17- 11/26
# days/yr in best 10 day period	0	2.6	2.6	1.3

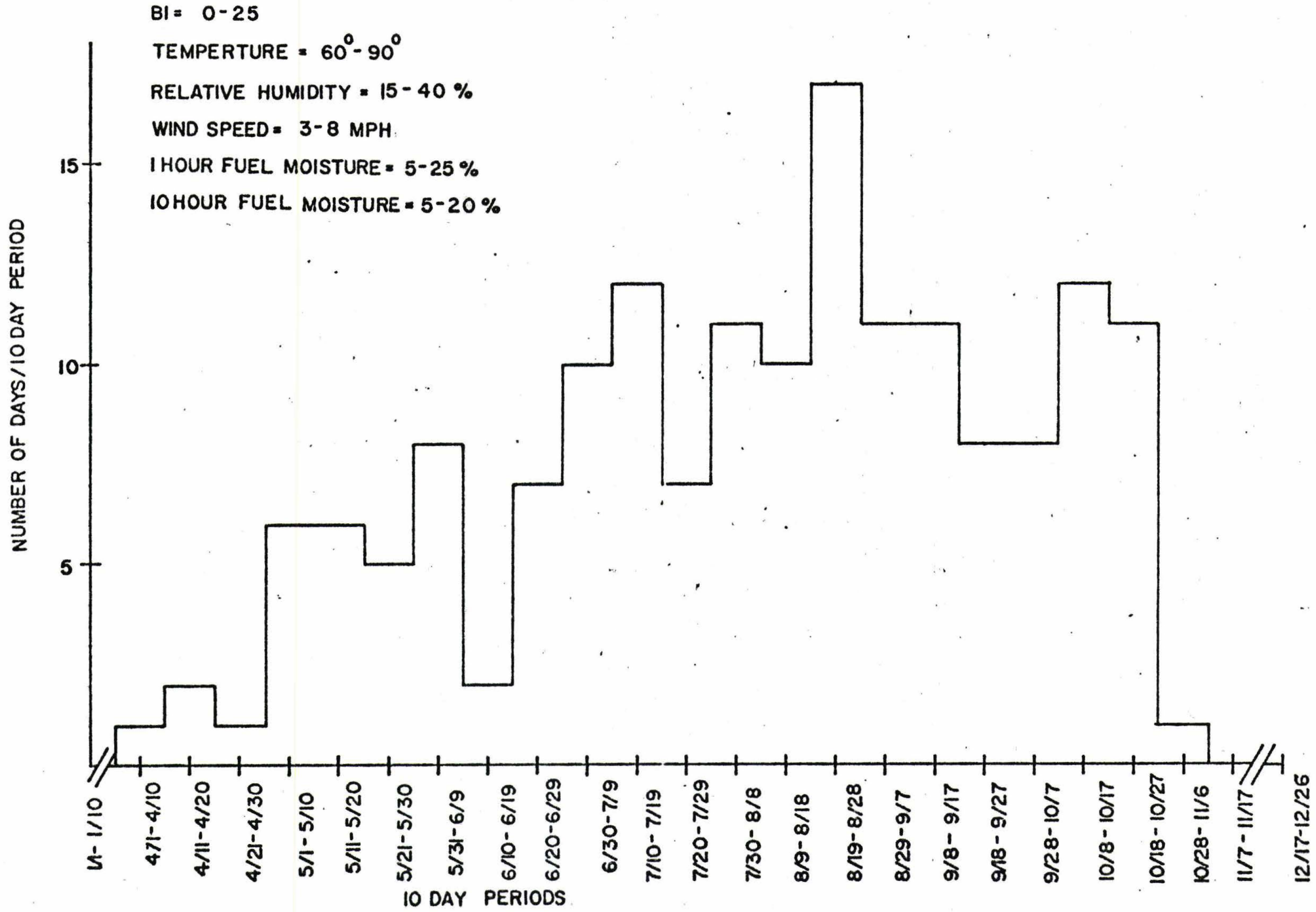

Figure 9. Ten days data for Nemo Station, fuel model E, prescription #6. Graph shows total number of days for each 10 day period, which met the given prescription, over the entire 10 year period.

Chapter 6. Summary

Possible Burning Program

From the data presented above in the text, tables, and graphs in appendix and by examination of the computer output, we feel that a substantial number of satisfactory days for a prescribed burning program in the Black Hills will occur, but only if the original prescription parameters recommended to us, especially the upper limit on 10-hour timelag fuel moisture, are slightly relaxed. Burning looks most likely to succeed in the month of October, as this month consistantly gave higher numbers of occurrence, other than the summer months of July and August. May could also provide favorable conditions for burning, but the chances of succeeding seem lest likely. The best 10 day periods for all fuel types and all stations seem to be October 8 to October 17 or October 18 to October 27. Burning during the period of May 11 to May 20 seems possible in fuels similar to NFDR fuel models C and E. In fuels similar to NFDR fuel model A (grasslands) the best month seems to be September and the best 10 day period September 28 to October 7. This is not to say that conditions might not be favorable at other times of the year, but from our study these periods consistantly produced the highest number of days over the entire 10 year period.

Prescriptions used in this study were written primarily for fuel models and not specific fuels. It is generally better to write a burning prescription for the fuel present and the objectives to be accomplished. In recommending a prescription for each fuel model the fire behavior graphs were studied and the data analysis examined so as to provide a prescription which would hopefully accomplish the desired results and also have the greatest possibility of occurring frequently. The prescriptions recommended therefore are:

	Fuel Model A	Fuel Model C	Fuel Model E
TEMPERATURE	65-80°	40-65°	40-65°
RELATIVE HUMIDITY	10-30%	15-40%	15-40%
WIND SPEED	5-10MPH	5-10MPH	5-15MPH
1 HR FUEL MOISTURE	5-12%	5-15%	5-15%
10 HR FUEL MOISTURE	--	5-10%	5-15%

The parameter, Burning Index, which is a combined expression of the above weather features, was used in our trial prescriptions, but was never limiting; that is, it never by itself caused a day of record to be judged unsatisfactory for burning. It is felt that these prescriptions or ones similar will have a reasonable chance of occurring each year, and will provide conditions to accomplish the desired results.

Assumptions

During this research two assumptions were made, and the findings reported and recommendations made are based on these assumptions. The assumptions made are:

A. The climatological trends over the last ten years will continue, i.e., the weather, and fuel moisture trends will not change drastically in the future.

B. Fire behavior parameters based on Rothermel's spread model have two basic assumptions, i.e., fuel models are representative of what is there, and assumes a continuous homogenious fuel bed.

Methodology Developed

A computer-based methodology was developed during this study to compare a trial burning prescription to archived weather records of the National Fire Weather Data Library. The methodology provides a fast tabulation of the frequency of satisfactory burning days at any fire weather station represented in the library. Additional development of the software and user procedures is continuing with a final availability expected in December, 1976.

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Appendix A

Following is a listing of the Fortran 4, computer program FIRECOR. FIRECOR was used in this research to obtain the frequency of favorable burning conditions. It was written for a CDC 6400 computer, but with some modifications could be fitted to any machine capable of compiling the Fortran computer language. The variables are listed with the program and also are listed in the text.

Cards for this program are on file with the Forest Fire Science Program, Department of Forest and Wood Sciences, Colorado State University, Fort Collins, Colorado 80523.

```
      OVERLAY(FIRE,0,0)
      PROGRAM DRIVER(INPUT,OUTPUT,TAPE5=INPUT,TAPE1,TAPE2,TAPE3,TAPE4,
     +TAPE6)
C
C********************************************************************************
C
C********************************************************************************
C
C                               PROGRAM FIRECOR
C
C     THIS PROGRAM IS PUT TOGETHER USING OVERLAYS,SO THAT CENTRAL
C     COMPUTER MEMORY SPACE CAN BE SAVED. THE OVERLAY NAME IS FIRE AND
C     THE PROGRAM AS A WHOLE IS TITLED FIRECOR.  FIRECOR IS A FORTRAN
C     4 COMPUTER PROGRAM DESIGNED TO OBTAIN THE FREQUENCY OF FAVORABLE
C     CONDITIONS FOR PRESCRIBED BURNING.  FIRECOR CONSISTS OF THREE
C     PROGRAMS TITLED PRESCRIBED FIRE(PREFIRE),COLDFRONT PASSAGE(FRNTPSG)
C     AND TEN DAYS(TENDAYS). PREFIRE CAN BE USED INDEPENDENTLY OF THE
C     OTHER PROGRAMS. TENDAYS MAYBE USED FOLLOWING PREFIRE WITHOUT USING
C     COLD FRONT PASSAGE.
C     INPUT TO FIRECOR IS FROM A MAGNETIC TAPE ON WHICH CONTAINS WEATHER
C     DATA AND NFDR INDEXES GENERATED BY PROGRAM FIRDAT(FURMAN AND
C     HELFMAN,1973). PRESCRIPTIONS ARE USED AS INPUT TO FIRECOR AND
C     THIS INFORMATION IS ON CARDS. THE FIRDAT DATA ON MAGNETIC TAPE IS
C     LABELED BY STATION NAME AND FUEL MODEL TYPE FOR EASY ACCESS. THE
C     COLD FRONT DATA IS ALSO ON THIS TAPE AND IT IS ALSO LABELED FOR
C     EASY ACCESS. TENDAYS INPUT CONSISTS OF A FILE CREATED IN THE OTHER
C     TWO PROGRAMS ALSO INPUT ON CARDS IS THE BEGINNING AND ENDING
C     MONTHS ANS DAY OF WEATHER RECORDS FOR EACH YEAR. THIS PROGRAM WAS
C     WRITTEN BY RUSSELL LEWIS----APRIL 1975.
C
C
C               VARIBLE LIST AND PUNCHING INSTRUCTIONS FOR FIRECOR
C
C     VARIBLE LIST---PREFIRE
C
C     HEAD= HEADER VARIBLE. LIST OF THE FIRDAT PARAMETERS SPECIFIED BY
C           THE USER. THESE ARE PRINTED ACROSS TOP OF PAGE
C     NAMEV= ALPHA NUMERIC NAME FOR A VARIBLE WITHIN A PRESCRIPTION--10
C           CHARACTERS
C     ICOLB= THE COLUMN FROM WEATHER DATA IN WHICH THE VARIBLE VALUE
C           BEGINS
C     ICOLE= THE COLUMN FROM WEATHER DATA IN WHICH THE VARIBLE VALUE ENDS
C     IVFMT= THE FIELD FORMAT THROUGH WHICH THE VARIBLE VALUE IS TO BE
C           READ. F-TYPE
C     VLO= THE LOWEST VALUE THE VARIBLE CAN HAVE TO SATISFY THE
C         PRESCRIPTION
C     VHI= THE HIGHEST VALUE THE VARIBLE CAN HAVE TO SATISFY THE
C         PRESCRIPTION
C     ICONST= THE CONSTRAINING ORDER OF THE VARIBLE
C     FMT= THE FORMAT GENERATED BY PREFIRE THROUGH WHICH A COMPLETE
C         WEATHER RECORD IS READ
C     FLD= THE ARRAY INTO WHICH THE WEATHER DATA IS STORED
C     IFLDREF= THIS ARRAY SERVES AS A CROSS REFERENCE TO FLD SO THAT
C             FLD(IFLDREF(1)) IS THE FIELD CONTAINING THE FIRST
C             PRESCRIPTION VARIBLE
C     NCON= THIS ARRAY SERVES AS A CROSS REFERENCE TO FLD SO THAT
C           FLD(IFLDREF(NCON(1))) IS THE FIELD CONTAINING THE VALUE OF
C           THE MOST CONSTRAINING VARIBLE OF THE PRESCRIPTION
C     FMTO= SAME AS FMT BUT FOR OUTPUT
```

```
C      NFILE= COUNTER OF THE PRESENT FILE BEING READ FROM WEATHER DATA
C      NPRE= COUNTER OF THE PRESENT PRESCRIPTION
C      NCHARS= THE NUMBER OF CHARACTERS FROM WEATHER DATA(USUALLY 80)
C      N= THE NUMBER OF VARIBLES IN THE PRESCRIPTION(UP TO 20)
C      NDSETS= THE NUMBER OF WEATHER DATA SETS,IE. THE NUMBER OF FILES ON
C              TAPE1
C      NPRESC= THE NUMBER OF PRESCRIPTIONS TO BE PROCESSED
C      NTFILE= THE TOTAL NUMBER OF FILES WRITTEN TO TAPE2
C      LBLFLG= FLAG USED AS AN INDICATOR THAT FRNTPSG IS TO BE OMITTED.
C              WILL CAUSE DATA TO FLOW TO TAPE6. IF=1 FRNTPSG TO BE
C              OMITTED
C      NAMEF= ALPHA NUMERIC NAME OF THE FUEL MODEL--10 CHARACTERS
C      ISTNNO= THE STATION NUMBER
C      NAMES= STATION NAME
C      IPRF= A PRINT FLAG. IF=1.PRINTING OF DAYS SATISFYING PRESCRIPTION
C            IS SUPPRESSED
C      NWR= A COUNTER OF THE NUMBER OF WEATHER RECORDS READ
C      NSD= A COUNTER OF THE NUMBER OF DAYS SATISFYING THE PRESCRIPTION
C      PDF= PREVIOUS DAY FLAG. IF=T.THE PREVIOUS DAY SATISFIED THE
C           PRESCRIPTION
C      NFLDS= THE NUMBER OF FIELDS WITHIN ONE WEATHER DATA RECORD
C      NC= THE NUMBER OF THE VARIBLE WITH THE PRESENT ORDER OF CONSTRAINT
C      NFLD= THE NUMBER OF THE FIELD CONTAINING THE ABOVE VARIBLE
C      PSD= THE PERCENT OF DAYS SATISFIED TO THE TOTAL DAYS CHECKED
C
C      VARIBLE LIST---FRNTPSG
C
C      ICFD= ARRAY IN WHICH THE COLD FRONT DATA IS STORED
C      IFILDES= STATION AND FUEL MODEL NAMES
C      IDUM= STATION NUMBERS AND WEATHER DATA
C      NFILES= NUMBER OF FILES TO BE PROCESSED
C      NFILESRD= NUMBER OF FILES READ
C      NRECSRD= NUMBER OF RECORDS READ
C      NRECSEL= NUMBER OF RECORDS ELIMINATED
C      IY= YEAR
C      MO= MONTH
C      ID= DAY
C      PCT= PERCENT OF THE RECORDS ELIMINATED,TO TOTAL NUMBER CHECKED
C
C      VARIBLE LIST---TENDAYS
C
C      MATRIX= THE ARRAY OF 10 DAY PERIODS BUILT BY THE PROGRAM
C      ITITL= STATION NAME- FUEL MODEL- PRESCRIPTION NUMBER
C      IMB= MONTH RECORD BEGAN
C      IME= MONTH RECORD ENDS
C      IDB= DAY RECORD BEGAN
C      IDE= DAY RECORD END
C      ICOMNT= ARRAY WITH ALPHA NUMERIC DATA,ALL,PART,OR NONE
C      SUM= SUM OF DAYS FOR EACH YEAR
C      SSUM= SQUARE OF THE SUM
C      CT= COMPLETE TEN DAY PERIODS
C      AVE= AVERAGE NUMBER OF DAYS
C      NDSETS= NUMBER OF DATA SETS OR FILES TO BE PROCESSED
C      LBLFLG= FLAG WHICH TELLS TENDAYS TO READ DATA FROM TAPE6
C      IY= YEAR
C      MO= MONTH
C      ID= DAY
C      IFM= INDEX FOR MONTH
C      IFD= INDEX FOR DAY
```

```
      C       NDX= INDEX
      C       NDXB= INDEX FOR BEGINNING
      C       NDXE= INDEX FOR ENDING
      C       INDX= INDEX
      C       INCB= INCREMENT BEGIN
      C       INCE= INCREMENT END
      C       IS= VALUE USED FOR DO LOOP
      C       IE= VALUE USED FOR DO LOOP
      C
      C       VARIBLES LIST--STAT
      C
      C       SUMX= SUM OF X
      C       SUMX2= SUM OF EACH X SQUARED
      C       SSUMX= SUM OF X SQUARED
      C       XBAR= AVERAGE OF X
      C       SS= SUM OF SQUARES(VARIANCE)
      C       S= STANDARD DEVIATION
      C       IDP= ARRAY WITH TEN DAY PERIODS
      C       IDP2= CONTINUATION OF IDP
      C       N= NUMBER OF YEARS IN WHICH RECORDS WERE TAKEN
      C
      C       PUNCHING INSTRUCTIONS---DATA INPUT
      C
      C       THESE ARE PUNCHING INSTRUCTIONS FOR THE PROGRAM. THERE ARE FOUR
      C       TYPES OF DATA CARDS USED IN FIRECOR THESE TYPES ARE AS FOLLOWS----
      C                 TYPE 1 = DATA SET VARIBLES
      C                 TYPE 2 = PRESCRIPTION PARAMETERS
      C                 TYPE 3 = STATION AND FUEL MODEL INFORMATION
      C                 TYPE 4 = TEN DAYS DATA
      C
      C    CARD      READ BY    NO.CARDS    VARIBLE    COLUMN    FORMAT  DESCRIPTION
      C    TYPE                               NAME                        OF VARIBLE
      C
      C    HEADER     PREFIRE       1          HEAD       1-80      8A10 HEADER FOR
      C                                                              FIRDAT PARAMETERS
      C                                                              ON OUTPUT PAGE
      C      1        PREFIRE       1          NCHARS     1-5        I5    NUMBER OF
      C                                                                 CHARACTERS
      C                                                                 PER WEATHER
      C                                                                RECORD-135
      C                                          N         6-10      I5  NUMBER OF
      C                                                                 VARIBLES-20
      C      1        PREFIRE       1          NDSETS     1-5        I5  NUMBER OF
      C                                                              DATA SETS-20
      C                                        NPRESC     6-10       I5  NUMBER OF
      C                                                              DIFFERENT
      C                                                              PRESCRIPTIONS
      C                                           LBLFLG   11-15    I5   FLAG OMITTING
      C                                                              FRNTPSG
      C      2        PREFIRE    UP TO 20    NAMEV      1-10       A10  NAME OF
      C                                                                 VARIBLE
      C                                        ICOLB      13-15      I3  COL.IN WHICH
      C                                                              VALUE FOR
      C                                                              THIS VARIBLE
      C                                                        BEGINS ON WEATHER REC.
      C                                        ICOLE      18-20      I3  COL.IN WHICH
      C                                                          VALUE FOR VARIBLE
      C                                                              ENDS
      C                                        IVFMT      21-30     A10  FORMAT FOR
```

THIS IS RECYCLED PAPER · "WASTE NOT® BOND". THIS FORM IS RECYCLABLE "WASTE NOT® BOND" IS A TRADEMARK OF SHADE INFORMATION SYSTEMS

```
C                                                     VARIBLE
C                               VLO      31-40    F10.2  LOW VALUE
C                                                     FOR VARIBLE
C                               VHI      41-50    F10.2  HIGH VALUE
C                                                     FOR VARIBLE
C                               ICONST   54-55      I2   ESTIMATED
C                                                    ORDER OF A
C                                                    CONSTRAINT
C
C     3     PREFIRE       1     NAMEF     1-10     A10   NAME OF FUEL
C                                                     MODEL
C                               ISTNNO   11-20     I10   NUMBER OF
C                                                     THE STATION
C                               NAMES    21-30     A10   NAME OF
C                                                       STATION
C                               IPRF       35      I1    A PRINT FLAG
C
C     1     FRNTPSG       1     NFILES    1-5      I5    NUMBER OF
C                                                     FILES TO BE
C                                                     PROCESSED
C     3     FRNTPSG       1     IFILDES   1-30    3A10   STATION NAME
C                                                  AND FUEL MODEL
C     1     TENDAYS             NDSETS    1-5      I5    NUMBER OF
C                                                     DATA SETS TO
C                                                     BE PROCESSED
C                                LBLFLG    6-10     I5   FLAG TELLING
C                                                    TO READ TAPE6
C     3     TENDAYS       1      ITITL    1-80    8A10   STATION NAME
C                                                    AND FUEL TYPE
C                                                    AND PRESCRIP-
C                                                    TION NUMBER
C     4     TENDAYS     1 CARD FOR  IMB   1-5      I5   MONTH RECORDS
C                       EACH YEAR                         BEGAN
C                                IDB      6-10     I5   DAY RECORDS
C                                                         BEGAN
C                                IME     11-15     I5   MONTH RECORDS
C                                                          END
C                                IDE     16-20     I5    DAY RECORDS
C                                                          END
C
C      COMMENTS ON PUNCHING DATA CARDS---
C       1) PUNCH DECIMAL POINT ON VLO AND VHI VALUES EX. 5. AND 10.
C       2) ALL DATA NUMBERS ARE TO BE RIGHT JUSTIFIED
C       3) PRESCRIPTION VARIBLES(CARD TYPE 2) ARE ALL ON 1 CARD,IE., EACH
C          PARAMETER AND ITS VALUES ARE ON 1 CARD
C
C                           ***********  NOTES  ***********
C      1) HEADER CARD OF FIRDAT PARAMETERS IS USER SPECIFIED
C      2) PROGRAM IS SET UP TO BE USED FOR ANY NUMBER OF YEARS. IN FRONT
C         PASSAGE AND TENDAYS A FEW CHANGES ARE NEEDED TO ACCOMMADATE THE
C         NUMBER OF YEARS SPECIFIED BY THE USER.  CHANGES NEEDED ARE IN
C         DIMENSION STATEMENTS AND IN SUBROUTINE STAT, THE VARIBLE N.
C
C************************************************************************
C
C************************************************************************
C      THIS LITTLE PROGRAM IS CALLED A ZERO OVEFLAY AND WILL CALL THE
C      THREE PRIMARY OVERLAYS. THE PROGRAM IS TITLED DRIVER.
C************************************************************************
```

```
C
C***********************************************************************
C     CALL THE OVERLAYS
C***********************************************************************
C
      CALL OVERLAY(4HFIRE,1,0,6HRFCALL)
      CALL OVERLAY(4HFIRE,2,0,6HRFCALL)
      CALL OVERLAY(4HFIRE,3,0,6HRFCALL)
      STOP
      END
      OVERLAY(FIRE,1,0)
      PROGRAM PREFIRE
C
C*******************************************************************************
C     THIS PROGRAM IS TITLED PREFIRE. FOR ANY GIVEN PRESCRIPTION WITH AS
C     MANY AS 20 PARAMETERS, PREFIRE WILL SEARCH THE WEATHER RECORDS OF A
C     SPECIFIED NUMBER OF DATA SETS AND LIST THE DAYS SATISFYING THE
C     GIVEN PRESCRIPTION. OUTPUT CAN BE ON PAPER,DISK,CARDS,ETC. OUTPUT
C     IS ALSO USED IN FRNTPSG AND IS ON A TEMPORARY DISK DESIGNATED AS
C     TAPE2,OR TAPE6 DEPENDING ON WHETHER FRONTAL PASSAGE IS TO BE USED
C     OR NOT.
C*******************************************************************************
C
      DIMENSION  NAMEV(20),ICOLB(20),ICOLE(20),IVFMT(20),VLO(20),VHI(20)
     +,ICONST(20),FMT(80),FLD(135),IFLDREF(20),NCON(20),FMTO(81)
      DIMENSION HEAD(18)
      INTEGER FMT,FMTO
      NFILE=0  $  NPRE=0  $  NTFILE=0
C
C*******************************************************************************
C     READ DATA DEFINITION CARD
C*******************************************************************************
C
      READ(5,903) (HEAD(I),I=1,18)
      READ(5,900) NDSETS,NPRESC
    1 READ(5,900) NCHARS,N,LBLFLG
      IF(EOF(5)) 802,110
  110 IF(N.GT.20)GO TO 801
C
C*******************************************************************************
C     READ PRESCRIPTION DEFINITION CARDS
C*******************************************************************************
C
      DO 2 I=1,N
      READ(5,901) NAMEV(I),ICOLB(I),ICOLE(I),IVFMT(I),VLO(I),VHI(I),ICON
     +ST(I)
      IF(ICONST(I).LT.1.OR.ICONST(I).GT.N)GO TO 800
      NCON(ICONST(I))=I
    2 CONTINUE
      NPRE=NPRE+1
C
C*******************************************************************************
C     CONSTRUCT THE DATA INPUT FORMAT
C*******************************************************************************
C
      CALL BLDFMT(NCHARS,N,ICOLB,ICOLE,IVFMT,FMT,IFLDREF,NFLDS,FMTO)
C
C*******************************************************************************
C     READ STATION AND FUEL MODEL INFORMATION
C*******************************************************************************
C
    3 NFILE=NFILE+1
      READ(5,902)NAMEF,ISTNNO,NAMES,IPRF
C
C*******************************************************************************
C     PRINT A HEADER
C*******************************************************************************
C
      PRINT 950,ISTNNO,NAMES,NAMEF,NFILE
      IF(IPRF.EQ.0)PRINT 961,(HEAD(I),I=1,18)
      IF(IPRF.EQ.0)PRINT 962
      IF(IPRF.EQ.1)PRINT 951
C
C***********************************************************************
C     INITIALIZE COUNTERS
C***********************************************************************
C
      NWR=0  $  NSD=0  $  PDF=0.
C
C***********************************************************************
C     READ WEATHER DATA
C***********************************************************************
C
    4 READ(1,FMT) (FLD(I),I=1,NFLDS)
      IF(EOF(1))700,5
    5 NWR=NWR+1
C
C***********************************************************************
C     CHECK THIS RECORD AGAINST THE PRESCRIPTION
C***********************************************************************
C
      DO 7  I=1,N
      NC=NCON(I)
      NFLD=IFLDREF(NC)
      IF(VLO(NC)-FLD(NFLD))6,7,10
    6 IF(VHI(NC)-FLD(NFLD))10,7,7
    7 CONTINUE
C
C***********************************************************************
C     HERE THIS RECORD SATISFIES THE PRESCRIPTION
C***********************************************************************
C
      IF(IPRF.EQ.0)PRINT FMTO,(FLD(I),I=1,NFLDS)
      IF(LBLFLG.EQ.1)GO TO 8
      WRITE(2,FMT)  (FLD(I),I=1,NFLDS)
      GO TO 9
    8 WRITE(6,FMT) (FLD(I),I=1,NFLDS)
    9 PDF=1.
      NSD=NSD+1
      GO TO 4
   10 IF(PDF.EQ.0.)GO TO 4  $  PDF=0.
      IF(IPRF.EQ.0)PRINT 960,NWR
      IF(IPRF.EQ.0)PRINT FMTO,(FLD(J),J=1,NFLDS)
   11 IF(IPRF.EQ.0)PRINT 952,NAMEV(NC),FLD(NFLD)
   12 I=I+1  $  IF(I.GT.N)GO TO 4
      NC=NCON(I)  $  NFLD=IFLDREF(NC)
      IF(VLO(NC)-FLD(NFLD))13,12,11
   13 IF(VHI(NC)-FLD(NFLD))11,12,12
  700 PRINT 950,ISTNNO,NAMES,NAMEF,NFILE
      PRINT 953
      PRINT 954,(NAMEV(I),VLO(I),VHI(I),I=1,N)
      PSD=FLOAT(NSD)/FLOAT(NWR)*100.
      PRINT 955,NWR,NSD,PSD
      ENDFILE 2
      IF(NFILE.LT.NDSETS)GO TO 3  $  NTFILE=NTFILE+NFILE  $  NFILE=0
      IF(NPRF.GE.NPRESC)GO TO 701  $  REWIND 1  $  GO TO 1
  701 PRINT 956,NTFILE
      GO TO 1000
  800 PRINT 957,ICONST(I),N
      STOP
  801 PRINT 958,N
      STOP
  802 PRINT 959
C
C***************************************************************************
C       FORMATS---INPUT
C***************************************************************************
C
  900 FORMAT(3I5)
  901 FORMAT(A10,2(2X,I3),A10,2F10.0,3X,I2)
  902 FORMAT(A10,I10,A10,4X,I1)
  903 FORMAT(5(A2,1X),A3,4(1X,A2),2(1X,A3),1X,I1,A2,1X,I2,A2,1X,I3,A2)
C
C***************************************************************************
C       FORMATS---OUTPUT
C***************************************************************************
C
  950 FORMAT(1H1,*----STATION NO.*,I10,*--*,A10,*--FUEL MODEL--*,A10,*--
     +FILE *,I2,* ON TAPE2*//)
  951 FORMAT(1H0,5(1H*),* RECORDS SATISFYING THE PRESCRIPTION FOR THE AB
     +OVE STATION AND FUEL MODEL WILL NOT BE PRINTED.*)
  952 FORMAT(5X,A10,*---*,F10.3)
  953 FORMAT(5X,*PRESCRIPTION DEFINED AS-   NAME                 FROM          T
     +O      */)
  954 FORMAT(29X,A10,2X,F10.4,2X,F10.4)
  955 FORMAT(1H0,5X,*NUMBER OF WEATHER DATA RECORDS=*,I6/,5X,*NUMBER OF
     +DAYS SATISFYING ABOVE PRESCRIPTION=*,I6/5X,*PERCENT=*,F6.2)
  956 FORMAT(//,10X,*TOTAL NUMBER OF FILES WRITTEN TO TAPE2 THIS RUN=*,I
     +2)
  957 FORMAT(//* ORDER OF *,I2,* NOT LEGAL.  ONLY FROM 1 TO *,I2,* CAN B
     +E USED.*)
  958 FORMAT(//* ILLEGAL VALUE OF *,I2,* READ AS NUMBER OF CONSTRAINTS.
     + USE 1 THROUGH 20.*)
  959 FORMAT(//* RAN OUT OF INPUT CARDS TOO SOON.*)
  960 FORMAT(* RECORD NO. *,I6,*.  THIS RECORD CAUSED A STRING OF DAYS T
     +O BE TERMINATED BECAUSE OF THE FOLLOWING VALUES:*)
  961 FORMAT(1H0,///,*THIS IS THE LISTING OF DAYS WHICH MET THE PRESCRIP
     +TION*/1H0,*AND THE DAYS WHICH CAUSED A STRING OF DAYS TO BE TERMIN
     +ATED.*/1H0,*THE PRESCRIPTION PARAMETERS WHICH CAUSED TERMINATION A
     +RE ALSO PRINTED AND THEIR VALUES.*/1H0,*NUM./DATE*,4X,5(A2,1X),A3,
     +1X,A2,2X,A2,3X,A2,2X,A2,1X,A3,2X,A3,3X,I1,A2,3X,I2,A2,1X,I3,A2)
  962 FORMAT(1X,135(*X*))
 1000 CONTINUE
      END
      SUBROUTINE BLDFMT(NCH,N,IB,IE,IFMT,FMT,IFLOR,NFLDS,FMTO)
C
C******************************************************************************
C     THIS SUBROUTINE BUILDS THE FORMAT WHICH WEATHER DATA IS READ
C     AND PRINTED
C******************************************************************************
C
      DIMENSION IB(1),IE(1),IFMT(1),FMT(1),IFLOR(1),FMTO(1),FMTCHS(14)
      INTEGER FMT,FMTO,FMTCHS
      DATA FMTCHS /2HA1 ,2HA2 ,2HA3 ,2HA4 ,2HA5 ,2HA6 ,2HA7 ,2HA8 ,2HA9
     +,3HA10 ,1H(,1H),1H,,4H(1X,/
C
C******************************************************************************
C     BUILD THE FORMAT
C******************************************************************************
C
      FMT(1)=FMTCHS(11)  $  FMTO(1)=FMTCHS(14)  $  NFLDS=0
      NDX=1  $  INDX=2  $  IPOS=1
    1 NAS=IB(NDX)-IPOS
      IF(NAS.EQ.0)GO TO 100
    2 IF(NAS.LE.10)GO TO 3
      NAS=NAS-10
      FMT(INDX)=FMTCHS(10)  $  FMT(INDX+1)=FMTCHS(13)
      FMTO(INDX)=FMTCHS(10) $  FMTO(INDX+1)=FMTCHS(13)  $  NFLDS=NFLDS+1
      INDX=INDX+2  $  IF(INDX.GE.80)GO TO 1000
      GO TO 2
    3 FMT(INDX)=FMTCHS(NAS)  $  FMT(INDX+1)=FMTCHS(13)  $  NFLDS=NFLDS+1
      FMTO(INDX)=FMTCHS(NAS) $  FMTO(INDX+1)=FMTCHS(13)
      INDX=INDX+2  $  IF(INDX.GE.80)GO TO 1000
C
C******************************************************************************
C     HERE INSERT THE F-TYPE FORMAT
C******************************************************************************
C
  100 FMT(INDX)=IFMT(NDX)  $  FMT(INDX+1)=FMTCHS(13)  $  IPOS=IE(NDX)+1
      FMTO(INDX)=IFMT(NDX)  $  FMTO(INDX+1)=FMTCHS(13)  $  NFLDS=NFLDS+1
      IFLOR(NDX)=NFLDS  $  INDX=INDX+2  $  IF(INDX.GE.80)GO TO 1000
      NDX=NDX+1  $  IF(NDX.GT.N)GO TO 200  $  GO TO 1
C
C******************************************************************************
C     HERE ALL F-FORMATS DONE.FINISH THE RECORD
C******************************************************************************
C
  200 NAS=NCH-IPOS+1
      IF(NAS.EQ.0)GO TO 300
  201 IF(NAS.LE.10)GO TO 202
      NAS=NAS-10  $  FMT(INDX)=FMTCHS(10)  $  FMTO(INDX)=FMTCHS(10)
      FMT(INDX+1)=FMTCHS(13)  $  FMTO(INDX+1)=FMTCHS(13)
      INDX=INDX+2  $  IF(INDX.GE.80)GO TO 1000  $  NFLDS=NFLDS+1
      GO TO 201
  202 FMT(INDX)=FMTCHS(NAS)  $  FMTO(INDX)=FMTCHS(NAS)  $  NFLDS=NFLDS+1
  300 FMT(INDX+1)=FMTCHS(12)  $  FMTO(INDX+1)=FMTCHS(12)
      IF(INDX.GT.80)GO TO 1000  $  INDX=INDX+2
      DO 301 I=INDX,80
      FMT(I)=10H
  301 FMTO(I)=10H
      PRINT 900,(FMT(I),I=1,INDX)
      RETURN
 1000 PRINT 901,NDX
```

```
          STOP
      900 FORMAT(* FORMAT FOR READING WEATHER DATA-*/(1X,13A10))
      901 FORMAT(* NEED TO MAKE FORMAT ARRAYS LARGER AND REVISE BLDFMT.  LAS
         +T VARIABLE NUMBER= *,I2)
          END
      OVERLAY(FTPE,2,0)
      PROGRAM FRNTPSG
C
C****************************************************************************
C     THIS PROGRAM ENTITLED FRONTAL PASSAGE(FRNTPSG) IS DESIGNED TO
C     CHECK THE DAYS WHICH PASSED THE PRESCRIPTION, AGAINST DAYS WHEN A
C     COLD FRONT CAME THROUGH THE AREA. INPUT DATA(WEATHER) READ FROM
C     A TAPE ONTO A FILE DESIGNATED AS TAPE3. DATA FROM  PREFIRE IS ON
C     A FILE CALLED TAPE2,AND OUTPUT FROM FRNTPSG IS ON TAPE4.
C****************************************************************************
C
        DIMENSION ICFD(10,12,31),IFILDES(20,3),IDUM(8)
      REWIND 2  $  REWIND 4
C
C****************************************************************************
C     READ DATA SET INFORMATION
C****************************************************************************
C
      READ 900, NFILES
      IF(NFILES.EQ.0)GO TO 1000
      DO 1 I=1,NFILES
      READ 901, (IFILDES(I,J),J=1,3)
    1 CONTINUE
C
C****************************************************************************
C     LOAD ICFD MATRIX AND INITIALIZE COUNTERS
C****************************************************************************
C
    2 CALL LOADMAT(ICFD)
      NFILESR=0
    3 NRECSRD=0  $  NRECSEL=0
C
C****************************************************************************
C     READ PREFIRE DATA FROM TAPE2
C****************************************************************************
C
    4 READ(2,902) IDUM(1),IY,MO,ID,(IDUM(I),I=2,8)
      IF(EOF(2))10,5
    5 NRECSRD= NRECSRD+1
C
C****************************************************************************
C     CHECK FRONT PASSAGE FOR THIS DAY
C****************************************************************************
C
      IF(ICFD(IY,MO,ID).EQ.0)GO TO 6
      NRECSEL=NRECSEL+1  $  GO TO 4
    6 WRITE(4,902) IDUM(1),IY,MO,ID,(IDUM(I),I=2,8)
      GO TO 4
   10 NFILESR=NFILESR+1
      PRINT 950
      PRINT 951, (IFILDES(NFILESR,J),J=1,3)
      PRINT 952,NFILESR,NRECSRD,NRECSEL
      PCT=FLOAT(NRECSEL)/FLOAT(NRECSRD)*100.
      PRINT 953,PCT
      IF(NFILESR.GE.NFILES)GO TO 1000
      ENDFILE 4
      GO TO 3
C
C****************************************************************************
```

```
C     FORMATS---INPUT--OUTPUT
C*****************************************************************************
C
  900 FORMAT(I5)
  901 FORMAT(3A10)
  902 FORMAT(A6,3I2,6A10,A8)
  950 FORMAT(///,1X,*THIS TABLE IS OUTPUT FROM FRNTPSG. IT GIVES EACH FU
     +EL MODEL,*/1H0,*HOW MANY RECORDS WERE READ, HOW MANY WERE ELIMINAT
     +ED.*/1H0,*AND THE PERCENTAGE OF THE RECORDS ELIMINATED.*)
  951 FORMAT(1H0,52X,3A10)
  952 FORMAT(1H0,5X,*FILE NUMBER *,I3,*;   NUMBER OF RECORDS READ= *,I6,
     +*, NUMBER OF RECORDS ELIMINATED= *,I6,*.*)
  953 FORMAT(* ----- PER CENT OF RECORDS ELIMINATED= *F5.2)
 1000 CONTINUE
      END
```

```
SUBROUTINE  LOADMAT                              CDC 6400 FTN V3.0-P365 OPT=1  04/08/76  12.14.25.        PAGE      1

      SUBROUTINE LOADMAT(ICFD)
C
C*****************************************************************************
C     THIS SUBROUTINE READS THE COLD FRONT DATA FROM TAPE3,AND LOADS IT
C     IN A MATRIX TO BE CHECKED.
C*****************************************************************************
C
      DIMENSION ICFD(10,12,31)
      READ(3,900) (((ICFD(I,J,K),K=1,31),J=1,12),I=1,10)
  900 FORMAT(1X,31I1)
      RETURN
      END
      OVERLAY(FIPE,3,0)
      PROGRAM TENDAYS
C
C*****************************************************************************
C     THIS PROGRAM IS TITLED TENDAYS AND IS DESIGNED TO COMPUTE THE
C     NUMBER OF DAYS, IN EACH TEN DAY PERIOD, IN EACH YEAR.THAT PASSED
C     THE PRESCRIPTION. IT COMPUTES THE MEAN NUMBER OF DAYS IN A TEN DAY
C     PERIOD AND THE STANDARD DEVIATION.IT THEN COMPUTES THE TOTAL
C     NUMBER OF DAYS IN EACH PERIOD SUMMED OVER THE ENTIRE 10 YEAR
C     PERIOD. INPUT IS ON CARDS, AND ON TAPE4.
C*****************************************************************************
C*****************************************************************************
C     DIMENSION THE ARRAYS
C*****************************************************************************
C
      DIMENSION MATRIX(10,36),ITITL(8),IMB(10),IME(10),IDB(10),IDE(10)
      DIMENSION ICOMNT(10,36),SUM(10),SSUM(10),CT(10)
      DIMENSION AVE(10)
      REWIND 4
      REWIND 6
C
C*****************************************************************************
C     READ IN THE DATA FROM CARDS
C*****************************************************************************
C
      READ 900, NDSETS,LBLFLG
      IFM=IFD=1
      DO 700 NTIMES=1,NDSETS
      READ 901,(ITITL(I),I=1,8)
      READ 902,(IMB(I),IDB(I),IME(I),IDE(I),I=1,10)
C
C*****************************************************************************
C     CALL INIT TO INITIALIZE THE ARRAY
C*****************************************************************************
C
      CALL INIT(MATRIX,ICOMNT,SUM,SSUM,AVE)
    1 IF(LBLFLG.EQ.1)GO TO 3
      READ(4,903) IY,MO,ID
      IF(EOF(4))600,2
    3 READ(6,903) IY,MO,ID
      IF(EOF(6))600,2
C
C*****************************************************************************
C     CALL GET INDEX(GETNDX)
C*****************************************************************************
C
    2 CALL GETNDX(IFM,IFD,MO,ID,NDX)
      INDX= (NDX-1)/10 +1
      IF(INDX.GT.36)GO TO 1  $  IYNDX=IY-63
      IF(IYNDX.GT.10)GO TO 1
      MATRIX(IYNDX,INDX)= MATRIX(IYNDX,INDX)+1
      GO TO 1
  600 DO 615 I=1,10
C*****************************************************************************
C     CALL GETNDX
C*****************************************************************************
C
      CALL GETNDX(IFM,IFD,IMB(I),IDB(I),NDXB)  $  INCR=0
```

THIS IS RECYCLED PAPER - WASTE NOT © BOND - THIS FORM IS RECYCLABLE WASTE NOT © BOND IS A TRADEMARK OF SHADE INFORMATION SYSTEMS

```
      CALL GETNDX(IFM,IFD,IME(I),IDE(I),NDXE)  $  INCE=0
      IF((MOD(NDXB,10)).NE.1)CALL FIXIT(MATRIX,ICOMNT,NDXB,I,INCB,1)
      IF((MOD(NDXE,10)).NE.0)CALL FIXIT(MATRIX,ICOMNT,NDXE,I,INCE,-1)
C
C≠≠≠≠≠≠≠≠≠≠≠≠≠≠≠≠≠≠≠≠≠≠≠≠≠≠≠≠≠≠≠≠≠≠≠≠≠≠≠≠≠≠≠≠≠≠≠≠≠≠≠≠≠≠≠≠≠≠≠≠≠≠≠≠≠≠≠≠≠≠≠≠≠≠≠≠≠≠≠
C     COMPUTE THE STATISTICS FOR THE YEARLY TABLE
C*********************************************************************************
C     COMPUTE THE STATISTICS FOR THE YEARLY TABLE
C*********************************************************************************
C
      IS=(NDXB-1)/10+INCB+1
      IE=(NDXE-1)/10+INCE+1
      IF(IE.GT.36)IE=36
      DO 605 J=IS,IE
      ICOMNT(I,J)=5HALL
      SUM(I)=SUM(I)+FLOAT(MATRIX(I,J))
      SSUM(I)=SSUM(I)+FLOAT(MATRIX(I,J)*MATRIX(I,J))
  605 CONTINUE
      CT(I)=IE-IS+1
      SSUM(I)=(SSUM(I)-(SUM(I)*SUM(I)/CT(I)))/(CT(I)-1.)
      SSUM(I)=SQRT(SSUM(I))
      AVE(I)=SUM(I)/CT(I)
  615 CONTINUE
C
C*********************************************************************************
C     NOW PRINT THE RESULTS----CALL SUBROUTINE PRINTER
C*********************************************************************************
C
      CALL PRINTR(MATRIX,ICOMNT,AVE,SUM,SSUM,CT,ITITL)
C
C*********************************************************************************
C     FORMATS---INPUT
C*********************************************************************************
C
  900 FORMAT(2I5)
  901 FORMAT(9A10)
  902 FORMAT(4I5)
  903 FORMAT(6X,3I2)
C
C*********************************************************************************
C     CALL SUBROUTINE STAT
C*********************************************************************************
C
      CALL STAT(MATRIX)
  700 CONTINUE
      END
      SUBROUTINE INIT(M,IC,S,SS,AVE)
C
C*********************************************************************
C     THIS SUBROUTINE IS USED TO INITIALIZE THE ARRAYS TO ZERO AND NONE
C*********************************************************************
C
      DIMENSION M(10,36),IC(10,36),S(10),SS(10)
      DIMENSION AVE(10)
      DO 1 I=1,10
      S(I)=0.
      SS(I)=0.
      AVE(I)=0.
      DO 1 J=1,36
      M(I,J)=0
      IC(I,J)=10HNONE
    1 CONTINUE
      RETURN  $  END
```

```
      SUBROUTINE GETNDX(IS,JS,IW,JW,NDX)
C
C*********************************************************************
C     THIS SUBROUTINE GENERATES THE INDEXES USED IN THE MAIN PROGRAM BY
C     THE MATRIX
C*********************************************************************
C
      DIMENSION IDIM(12)
      DATA IDIM/31,28,31,30,31,30,31,31,30,31,30,31/
      IF(IS.NE.IW)GO TO 1
      NDX= JW-JS+1
      RETURN
    1 NDX=0
      ISD=JS-1
      DO 2 I=IS,IW
      IED=IDIM(I)  $  IF(I.EQ.IW)IED=JW
      NDX=NDX+IED-ISD
    2 ISD=0
      RETURN  $  END
```

```
      SUBROUTINE FIXIT(M,IC,NDX,I,INC,IVAL)
C
C*********************************************************************
C     THIS SUBROUTINE SETS M((NDX-1/10,I)) TO ZERO,AND SETS
C     IC(NDX-1/10,I) TO PART, AND SETS INC TO IVAL
C*********************************************************************
C
      DIMENSION M(10,36),IC(10,36)
      INDX=(NDX-1)/10+1
      IF(INDX.GT.36)RETURN
      IC(I,INDX)=4HPART
      INC=IVAL
      RETURN  $  END
      SUBROUTINE PRINTR(M,IC,AVE,SUM,SSUM,CT,ITITL)
C
C*****************************************************************
C     THIS SUBROUTINE IS DESIGNED TO PRINT OUT THE RESULTS OF TENDAYS.
C     IT PRINTS A TABLE THAT GIVES THE NUMBER OF DAYS IN EACH TENDAY
C     PERIOD FOR EACH YEAR. A SECOND TABLE IS PRINTED WHICH GIVES THE
C     AVERAGE NUMBER OF DAYS/10DAY PERIOD,THE STANDARD DEVIATION,THE
C     TOTAL NUMBER OF DAYS FOR EACH YEAR,AND NUMBER OF COMPLETE 10 DAY
C     PERIODS.
C*****************************************************************
C
      DIMENSION M(10,36),IC(10,36),SUM(10),SSUM(10),CT(10)
      DIMENSION IDP(36),IDP2(36),ITITL(8)
      DIMENSION AVE(10)
      DATA IDP/10H01/01-01/1,10H01/11-01/2,10H01/21-01/3,10H01/31-02/0,
     +10H02/10-02/1,10H02/20-03/0,10H03/02-03/1,10H03/12-03/2,10H03/22-0
     +3/3,10H04/01-04/1,10H04/11-04/2,10H04/21-04/3,10H05/01-05/1,10H05/
     +11-05/2,10H05/21-05/3,10H05/31-06/0,10H06/10-06/1,10H06/20-06/2,10
     +H06/30-07/0,10H07/10-07/1,10H07/20-07/2,10H07/30-08/0,10H08/09-08/
     +1,10H08/19-08/2,10H08/29-09/0,10H09/08-09/1,10H09/18-09/2,10H09/28
     +-10/0,10H10/08-10/1,10H10/18-10/2,10H10/28-11/0,10H11/07-11/1,10H1
     +1/17-11/2,10H11/27-12/0,10H12/07-12/1,10H12/17-12/2/
      DATA IDP2/3*1H0,2*1H9,4*1H1,6*1H0,6*1H9,3*1H8,6*1H7,6*1H6/
C
C*****************************************************************
C     PRINT HEADER
C*****************************************************************
C
      PRINT 950
      PRINT 951, (ITITL(I),I=1,8)
      PRINT 952
      PRINT 953
C
C*****************************************************************
C     PRINT OUT THE RESULTS
C*****************************************************************
C
      DO 1 J=1,36
      PRINT 954, IDP(J),IDP2(J),(M(I,J),IC(I,J),I=1,10)
    1 CONTINUE
      PRINT 955
      PRINT 956,(I,I=1964,1973)
      PRINT 957,(AVE(I),I=1,10)
      PRINT 958,(SSUM(I),I=1,10)
      PRINT 959,(CT(I),I=1,10)
      PRINT 960,(SUM(I),I=1,10)
C
C*****************************************************************
C     FORMATS---OUTPUT
C*****************************************************************
C
  950 FORMAT(1H1,*THIS TABLE SHOWS THE ANALYSIS OF EACH 10 DAY PERIOD.FO
     +R EACH YEAR.*/1H0,*THE NUMBERS ARE THE TOTAL NUMBER OF DAYS WHICH
     +MET THE PRESCRIPTION IN THAT 10 DAY PERIOD.*/1H0,*THE WORDS NONE,P
     +ART,OR ALL INDICATE WHETHER ALL OF THE 10DAY PERIOD*/1H0,*WAS RECO
     +RDED OR JUST PART OF IT,OR NONE OF IT. IF A YEAR CONTAINS ALL ZERO
     +S,*/1H0,*AND THE WORD ALL APPEARS BY EACH ZERO,THIS USUALLY MEANS
     +THAT NO RECORDS AT ALL WERE TAKEN IN THAT YEAR.*/1H0,*EACH 10 DAY
     +PERIOD IS LABELED DOWN THE LEFT HAND SIDE, AND EACH YEAR IS LABELE
     +D ALONG THE TOP.*)
 951 FORMAT(1H0,55X,8A10)
 952 FORMAT(1X .2X.*PERIOD*.10X.*64*,10X,*65*,10X,*66*,10X,*67*,10X.*68
    +*.10X,*69*,10X,*70*,10X,*71*,10X,*72*,10X,*73*)
 953 FORMAT(1X .135(*X*))
 954 FORMAT(1X .A10,A1.1X,*X*.10(3X.I2,1X.A4,2X))
 955 FORMAT(1H1,*THIS TABLE IS THE RESULTS OF STATISTICS COMPUTATIONS.I
    +T CONSISTS OF*/1H0,*THE AVERAGE NUMBER OF DAYS PER 10 DAY PERIOD.T
    +HE STANDARD DEVIATION ABOUT THE MEAN,*/1H0,*THE NUMBER OF COMPLETE
    + 10 DAY PERIODS,AND THE TOTAL NUMBER OF DAYS FOR EACH YEAR.*/1H0,*
    +AVE=AVERAGE NO. DAYS PER 10 DAY PERIOD*/1H0,*SDEV=STANDARD DEVIATI
    +ON*/1H0.*CT=COMPLETE 10 DAY PERIODS*/1H0,*SUM=TOTAL NUMBER OF DAYS
    +*/1H0,*THE YEARS ARE PRINTED ACROSS THE TOP AND THE ABBREVIATIONS
    +DOWN THE LEFT HAND SIDE.*)
 956 FORMAT(1H0,/////,10X,I4,9(8X.I4))
 957 FORMAT(1H0,*AVE*,5X,F5.2.9(7X.F5.2))
 958 FORMAT(1H0.*SDEV*,4X,F5.2,9(7X,F5.2))
 959 FORMAT(1H0.*CT*,6X,F5.2,9(7X.F5.2))
 960 FORMAT(1H0,*SUM*,5X,F5.2,9(7X,F5.2))
     RETURN  $  END
```

```
      SUBROUTINE STAT(M)
C
C*****************************************************************
C     THIS SUBROUTINE IS DESIGNED TO ANALYZE EACH 10 DAY PERIOD OVER
C     THE ENTIRE 10 YEAR PERIOD. IT SUMS EACH 10 DAY PERIOD,TAKES THE
C     AVERAGE NUMBER OF DAYS IN THAT PERIOD PER YEAR AND THE STANDARD
C     DEVIATION ABOUT THE MEAN. THESE ARE PRINTED OUT IN TABULAR FORM.
C*****************************************************************
C
      DIMENSION M(10,36),SUMX(36),SUMX2(36),SSUMX(36),XBAR(36),SS(36)
      DIMENSION S(36),IDP(36),IDP2(36)
C
C*****************************************************************
C     INITIALIZE IDP AND IDP2 AND N
C*****************************************************************
C
      DATA IDP/10H01/01-01/1,10H01/11-01/2,10H01/21-01/3,10H01/31-02/0.
     +10H02/10-02/1,10H02/20-03/0.10H03/02-03/1,10H03/12-03/2,10H03/22-0
     +3/3.10H04/01-04/1.10H04/11-04/2.10H04/21-04/3,10H05/01-05/1.10H05/
     +11-05/2,10H05/21-05/3,10H05/31-06/0.10H06/10-06/1,10H06/20-06/2,10
     +H06/30-07/0,10H07/10-07/1.10H07/20-07/2,10H07/30-08/0,10H08/09-08/
     +1.10H08/19-08/2.10H08/29-09/0.10H09/08-09/1,10H09/18-09/2.10H09/28
     +-10/0,10H10/08-10/1,10H10/18-10/2,10H10/28-11/0,10H11/07-11/1,10H1
     +1/17-11/2,10H11/27-12/0,10H12/07-12/1,10H12/17-12/2/
      DATA IDP2/3*1H0.2*1H9,4*1H1.6*1H0,6*1H9,3*1H8,6*1H7,6*1H6/
      CALL WHY(SUMX,SUMX2,SSUMX,XBAR,SS,S)
      N=10
C
C*****************************************************************
C     COMPUTE THE MEAN AND STANDARD DEVIATION
C*****************************************************************
C
      DO 10 I=1,10
      DO 10 J=1.36
      SUMX(J)=SUMX(J)+M(I,J)
      SUMX2(J)=SUMX2(J)+(M(I,J)**2)
   10 CONTINUE
      DO 20 J=1,36
      XBAR(J)=SUMX(J)/N
      SSUMX(J)= SUMX(J)**2
      SS(J)= (SUMX2(J)-(SSUMX(J)/N))/(N-1)
      S(J)= SQRT(SS(J))
   20 CONTINUE
C
C*****************************************************************
C     PRINT THE RESULTS
C*****************************************************************
C
      PRINT 900
      PRINT 901  $  PRINT 902
      PRINT 903,(IDP(J),IDP2(J),SUMX(J),XBAR(J),S(J),J=1,36)
C
C*****************************************************************
C     FORMATS---OUTPUT
C*****************************************************************
C
  900 FORMAT(1H1,///////,*THIS TABLE SHOWS THE TOTAL NUMBER OF DAYS WHIC
     +H MET THE PRESCRIPTION IN EACH*/1H0,*10 DAY PERIOD FOR THE ENTIRE
     + 10 YEARS. ALSO COMPUTED ARE THE MEAN NUMBER OF DAYS/YEAR IN EACH*
     +/1H0,*PERIOD, AND THE STANDARD DEVIATION. 10 DAY PERIODS ARE PRINT
     +ED DOWN THE*/1H0,*LEFT HAND SIDE WHILE SUM, AVERAGE, AND STANDARD
     + DEVIATION ARE ACROSS THE TOP.*)
 901 FORMAT(1H0,///,34X,*SUM*,32X,*AVE*,29X,*STD. DEV.*)
 902 FORMAT(1X,135(*X*))
 903 FORMAT((1X,A10,A1,1X,*X*,18X,F5.2,2(30X,F5.2)))
     RETURN  $  END
```

```
      SUBROUTINE WHY(SX,SX2,SSX,XB,SS2,S2)
C
C*****************************************************************************
C     THIS SUBROUTINE INITIALIZES THE VARIABLES USED IN STAT
C*****************************************************************************
C
      DIMENSION SX(36),SX2(36),SSX(36),XB(36),SS2(36),S2(36)
      DO 2 I=1,36
      SX(I)=0.  $  SX2(I)=0.  $  XB(I)=0.  $  SS2(I)=0.
      SSX(I)=0.
    2 S2(I)=0.
      RETURN  $  END
```

Appendix B

Appendix B is an example of the output from FIRECOR. There are several parts to the output which are listed below. The parts are:

1. Title of the station name, number, and fuel model type. This is followed by a listing of the days which met the prescriptions. The date is listed along with the weather record and NFDR indices. A string of days will be terminated by a dat which did not meet the prescription. This day is printed with its record, then immediately followed by the parameter(s) which caused the day not to pass.
2. The next part is the printing of the prescription variables and their values, followed by the number of records read, the number which met prescription, and the percent of days which met prescriptions.
3. The next part is from the coldfront program. Station and fuel model types are given along with the records read, the number of days eliminated and the percent of records eliminated.
4. Table showing each 10 day period, the number of days in that period for each year. Also words all, part or none appear, indicating whether all or part or none of the particular 10 day period was in the weather records taken in that year.
5. Table showing statistical analysis of the 10 days table.
6. Table giving sum, average, and standard deviation for each 10 day period over the entire 10 years.

```
THIS IS THE LISTING OF DAYS WHICH MET THE PRESCRIPTION

 AND THE DAYS WHICH CAUSED A STRING OF DAYS TO BE TERMINATED.

 THE PRESCRIPTION PARAMETERS WHICH CAUSED TERMINATION ARE ALSO PRINTED AND THEIR VALUES.

NUM./DATE     IG SC ER OI BI FLS TP  RH   WS  RK PGR  ADJ   1FM   10FM 100FM
XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
392603650901 38  3 10 39 2.  30 77. 30.  5.   5 15   8.0   5.0   0.0   0.0
RECORD NO.     134.  THIS RECORD CAUSED A STRING OF DAYS TO BE TERMINATED BECAUSE OF THE FOLLOWING VALUES;
392603650902 27 11  8 28 3.  40 74. 36. 12.   5 15  10.0   6.0   0.0   0.0
    REL. HUM. ---     36.000
392603651005 58  9 13 59 3.  51 73. 29.  9.   5  4   5.0   5.0   0.0   0.0
RECORD NO.     168.  THIS RECORD CAUSED A STRING OF DAYS TO BE TERMINATED BECAUSE OF THE FOLLOWING VALUES;
392603651006 41 13 11 42 4.  61 63. 49. 12.   5  4   7.0   7.0   0.0   0.0
    REL. HUM. ---     49.000
    D.B. TEMP ---     63.000
392603651104 56 11 13 57 4.  61 66. 26. 10.   5  4   5.0   5.0   0.0   0.0
RECORD NO.     198.  THIS RECORD CAUSED A STRING OF DAYS TO BE TERMINATED BECAUSE OF THE FOLLOWING VALUES;
392603651105 34  3 10 35 2.  30 58. 50.  5.   5  4   8.0   8.0   0.0   0.0
    REL. HUM. ---     50.000
    D.B. TEMP ---     58.000
392603660505 50 10 12 51 3.  51 74. 27. 10.   5 10   6.0   5.0   0.0   0.0
RECORD NO.     223.  THIS RECORD CAUSED A STRING OF DAYS TO BE TERMINATED BECAUSE OF THE FOLLOWING VALUES;
392603660506 27  2  9 28 2.  33 66. 40.  4.   5 10   9.0   8.0   0.0   0.0
    WIND SPEED---      4.000
    REL. HUM. ---     40.000
392603660806 47 12 12 48 4.  62 79. 23. 11.   5 10   6.0   5.0   0.0   0.0
RECORD NO.     286.  THIS RECORD CAUSED A STRING OF DAYS TO BE TERMINATED BECAUSE OF THE FOLLOWING VALUES;
392603660807 15  7  6 15 2.  23 66. 51. 10.   5 10  12.0  10.0   0.0   0.0
    REL. HUM. ---     51.000
392603660825 51 10 12 52 3.  50 79. 29. 10.   5 10   6.0   5.0   0.0   0.0
RECORD NO.     305.  THIS RECORD CAUSED A STRING OF DAYS TO BE TERMINATED BECAUSE OF THE FOLLOWING VALUES;
392603660826 61 15 13 63 4.  70 84. 22. 12.   5 10   5.0   4.0   0.0   0.0
    FFM       ---      4.000
    D.B. TEMP ---     84.000
392603660909 52 18 12 53 4.  61 80. 29. 14.   5 10   6.0   5.0   0.0   0.0
RECORD NO.     320.  THIS RECORD CAUSED A STRING OF DAYS TO BE TERMINATED BECAUSE OF THE FOLLOWING VALUES;
392603660910 44 24 11 45 5.  70 77. 35. 17.   5 10   7.0   6.0   0.0   0.0
    WIND SPEED---     17.000
    REL. HUM. ---     35.000
392603661006 58  6 13 59 3.  50 74. 27.  7.   5  4   5.0   5.0   0.0   0.0
RECORD NO.     347.  THIS RECORD CAUSED A STRING OF DAYS TO BE TERMINATED BECAUSE OF THE FOLLOWING VALUES;
392603661007 67  6 14 69 3.  50 73. 26.  6.   5  4   4.0   4.0   0.0   0.0
    FFM       ---      4.000
392603661008 57  6 13 58 3.  51 70. 30.  7.   5  4   5.0   5.0   0.0   0.0
RECORD NO.     349.  THIS RECORD CAUSED A STRING OF DAYS TO BE TERMINATED BECAUSE OF THE FOLLOWING VALUES;
392603661009 45 23 12 46 5.  71 49. 36. 16.   5  4   6.0   6.0   0.0   0.0
    WIND SPEED---     16.000
    REL. HUM. ---     36.000
    D.B. TEMP ---     49.000
392603661020 53  9 13 54 3.  52 68. 21.  9.   5  4   5.0   5.0   0.0   0.0
RECORD NO.     361.  THIS RECORD CAUSED A STRING OF DAYS TO BE TERMINATED BECAUSE OF THE FOLLOWING VALUES;
392603661021 20 11  8 21 3.  42 47. 50. 12.   5  4  10.0  10.0   0.0   0.0
    REL. HUM. ---     50.000
    D.B. TEMP ---     47.000
392603670522 24  5  8 25 2.  32 76. 29.  8.   5 15  10.0   6.0   0.0   0.0
```

```
392603670523 27 11  8 28 3.  40 76. 41. 12.   5 15  10.0   6.0   0.0   0.0
   EL.            4
392603670905 [illegible] 18 12 53 4.  60 80. 29. 14.   5 10   6.0   5.0   0.0   0.0
RECORD NO.     526.  THIS RECORD CAUSED A STRING OF DAYS TO BE TERMINATED BECAUSE OF THE FOLLOWING VALUES;
392603070906 52 20 12 53 5.  80 84. 30. 15.   5 10   6.0   5.0   0.0   0.0
    D.B. TEMP ---     84.000
392603071003 47 14 12 48 4.  62 78. 28. 12.   5  4   6.0   6.0   0.0   0.0
RECORD NO.     554.  THIS RECORD CAUSED A STRING OF DAYS TO BE TERMINATED BECAUSE OF THE FOLLOWING VALUES;
392603071004 47  4 12 48 2.  30 59. 33.  5.   5  4   6.0   6.0   0.0   0.0
    REL. HUM. ---     33.000
    D.B. TEMP ---     59.000
392603080414 49  7 12 50 3.  51 67. 30.  8.   5 10   6.0   5.0   0.0   0.0
RECORD NO.     596.  THIS RECORD CAUSED A STRING OF DAYS TO BE TERMINATED BECAUSE OF THE FOLLOWING VALUES;
392603080415 66 12 14 68 4.  71 69. 13. 10.   5 10   4.0   3.0   0.0   0.0
    FFM       ---      3.000
392603080601 36  5 10 37 2.  31 67. 30.  7.   5 15   8.0   5.0   0.0   0.0
RECORD NO.     644.  THIS RECORD CAUSED A STRING OF DAYS TO BE TERMINATED BECAUSE OF THE FOLLOWING VALUES;
392603080602 37  3 10 38 2.  31 75. 34.  5.   5 15   8.0   5.0   0.0   0.0
    REL. HUM. ---     34.000
392603080912 52  7 12 53 3.  51 80. 29.  8.   5 10   6.0   5.0   0.0   0.0
RECORD NO.     746.  THIS RECORD CAUSED A STRING OF DAYS TO BE TERMINATED BECAUSE OF THE FOLLOWING VALUES;
392603080913 29  6  9 30 2.  32 76. 44.  8.   5 10   9.0   8.0   0.0   0.0
    REL. HUM. ---     44.000
392603080920 49 14 12 50 4.  60 70. 30. 12.   5 10   6.0   5.0   0.0   0.0
RECORD NO.     754.  THIS RECORD CAUSED A STRING OF DAYS TO BE TERMINATED BECAUSE OF THE FOLLOWING VALUES;
392603080921 42 13 11 43 4.  61 70. 40. 12.   5 10   7.0   6.0   0.0   0.0
    REL. HUM. ---     40.000
392603081012 53 20 13 54 5.  82 70. 20. 14.   5  4   5.0   5.0   0.0   0.0
RECORD NO.     776.  THIS RECORD CAUSED A STRING OF DAYS TO BE TERMINATED BECAUSE OF THE FOLLOWING VALUES;
392603081013 79 12 15 81 4.  70 77. 16.  9.   5  4   3.0   3.0   0.0   0.0
    FFM       ---      3.000
392603081025 57  4 13 58 2.  31 67. 27.  5.   5  4   5.0   5.0   0.0   0.0
RECORD NO.     789.  THIS RECORD CAUSED A STRING OF DAYS TO BE TERMINATED BECAUSE OF THE FOLLOWING VALUES;
392603081026  0  0  0  0 0.  06 39. 92. 15.   5  4  30.0  31.0  25.0   0.0
    FFM       ---     31.000
    REL. HUM. ---     92.000
    D.B. TEMP ---     39.000
392603090513 39  7 11 40 3.  42 70. 30.  8.   5 10   7.0   6.0   0.0   0.0
RECORD NO.     828.  THIS RECORD CAUSED A STRING OF DAYS TO BE TERMINATED BECAUSE OF THE FOLLOWING VALUES;
392603090514 50  5 12 51 2.  31 71. 34.  6.   5 10   6.0   5.0   0.0   0.0
    REL. HUM. ---     34.000
392603090704 36  5 10 37 2.  30 71. 27.  7.   5 15   8.0   5.0   0.0   0.0
RECORD NO.     880.  THIS RECORD CAUSED A STRING OF DAYS TO BE TERMINATED BECAUSE OF THE FOLLOWING VALUES;
392603090705 27  9  8 28 3.  41 76. 41. 11.   5 15  10.0   6.0   0.0   0.0
    REL. HUM. ---     41.000
392603090807 38 10 10 39 3.  40 79. 29. 11.   5 15   8.0   5.0   0.0   0.0
RECORD NO.     914.  THIS RECORD CAUSED A STRING OF DAYS TO BE TERMINATED BECAUSE OF THE FOLLOWING VALUES;
392603090808 61 20 13 63 5.  80 84. 14. 14.   5 15   5.0   3.0   0.0   0.0
    FFM       ---      3.000
    D.B. TEMP ---     84.000
392603090905 49 20 12 50 5.  80 69. 29. 15.   5 10   6.0   5.0   0.0   0.0
RECORD NO.     943.  THIS RECORD CAUSED A STRING OF DAYS TO BE TERMINATED BECAUSE OF THE FOLLOWING VALUES;
392603090906 59  6 13 61 3.  51 75. 25.  7.   5 10   5.0   4.0   0.0   0.0
    FFM       ---      4.000
392603090912 47  6 12 48 3.  42 80. 22.  7.   5 10   6.0   5.0   0.0   0.0
RECORD NO.     950.  THIS RECORD CAUSED A STRING OF DAYS TO BE TERMINATED BECAUSE OF THE FOLLOWING VALUES;
392603090913 59  2 13 61 2.  31 78. 25.  0.   5 10   5.0   4.0   0.0   0.0
    FFM       ---      4.000
    WIND SPEED---      0.000
392603090914 50  7 12 51 3.  50 75. 28.  8.   5 10   6.0   5.0   0.0   0.0
RECORD NO.     952.  THIS RECORD CAUSED A STRING OF DAYS TO BE TERMINATED BECAUSE OF THE FOLLOWING VALUES;
392603090915 41  7 11 42 3.  40 64. 38.  8.   5 10   7.0   6.0   0.0   0.0
    REL. HUM. ---     38.000
    D.B. TEMP ---     64.000
392603090929 50 18 12 51 4.  60 73. 29. 14.   5 10   6.0   5.0   0.0   0.0
```

```
    PRESCRIPTION DEFINED AS-   NAME            FROM          TO

                             BURN INDEX       0.0000       12.0000
                             D.B. TEMP       65.0000       80.0000
                             REL. HUM.       10.0000       30.0000
                             WIND SPEED       5.0000       15.0000
                             FFM              5.0000       15.0000

     NUMBER OF WEATHER DATA RECORDS=  1699
    NUMBER OF DAYS SATISFYING ABOVE PRESCRIPTION=     47
    PERCENT=  2.77


          TOTAL NUMBER OF FILES WRITTEN TO TAPE2 THIS RUN= 1


THIS TABLE IS OUTPUT FROM FRNTPSG. IT GIVES EACH FUEL MODEL,

HOW MANY RECORDS WERE READ, HOW MANY WERE ELIMINATED.

AND THE PERCENTAGE OF THE RECORDS ELIMINATED.

                                                  NEMO-MODEL A

      FILE NUMBER    1!    NUMBER OF RECORDS READ=       47, NUMBER OF RECORDS ELIMINATED=        8.
----- PER CENT OF RECORDS ELIMINATED= 17.02
```

```
THE NUMBERS ARE THE TOTAL NUMBER OF DAYS WHICH MET THE PRESCRIPTION IN THAT 10 DAY PERIOD•

THE WORDS NONE•PART•OR ALL INDICATE WHETHER ALL OF THE 10DAY PERIOD

WAS RECORDED OR JUST PART OF IT•OR NONE OF IT• IF A YEAR CONTAINS ALL ZEROS•

AND THE WORD ALL APPEARS BY EACH ZERO•THIS USUALLY MEANS THAT NO RECORDS AT ALL WERE TAKEN IN THAT YEAR•

EACH 10 DAY PERIOD IS LABELED DOWN THE LEFT HAND SIDE• AND EACH YEAR IS LABELED ALONG THE TOP•

                                          NEMO---FUEL MODEL A---PRESC--10
   PERIOD         64        65        66        67        68        69        70        71        72        73
XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
01/01-01/10 X    0 ALL     0 NONE    0 NONE    0 NONE    0 NONE    0 NONE    0 NONE    0 NONE    0 NONE    0 NONE
01/11-01/20 X    0 ALL     0 NONE    0 NONE    0 NONE    0 NONE    0 NONE    0 NONE    0 NONE    0 NONE    0 NONE
01/21-01/30 X    0 ALL     0 NONE    0 NONE    0 NONE    0 NONE    0 NONE    0 NONE    0 NONE    0 NONE    0 NONE
01/31-02/09 X    0 ALL     0 NONE    0 NONE    0 NONE    0 NONE    0 NONE    0 NONE    0 NONE    0 NONE    0 NONE
02/10-02/19 X    0 ALL     0 NONE    0 NONE    0 NONE    0 NONE    0 NONE    0 NONE    0 NONE    0 NONE    0 NONE
02/20-03/01 X    0 ALL     0 NONE    0 NONE    0 NONE    0 NONE    0 NONE    0 NONE    0 NONE    0 NONE    0 NONE
03/02-03/11 X    0 ALL     0 NONE    0 NONE    0 NONE    0 NONE    0 NONE    0 NONE    0 NONE    0 NONE    0 NONE
03/12-03/21 X    0 ALL     0 NONE    0 NONE    0 NONE    0 NONE    0 NONE    0 NONE    0 NONE    0 NONE    0 NONE
03/22-03/31 X    0 ALL     0 NONE    0 NONE    0 NONE    0 NONE    0 NONE    0 NONE    0 NONE    0 NONE    0 NONE
04/01-04/10 X    0 ALL     0 NONE    0 NONE    0 NONE    0 ALL     0 NONE    0 NONE    0 NONE    0 NONE    0 NONE
04/11-04/20 X    0 ALL     0 NONE    0 NONE    0 PART    1 ALL     0 NONE    0 NONE    0 NONE    0 NONE    0 NONE
04/21-04/30 X    0 ALL     0 PART    0 NONE    0 ALL     0 ALL     0 ALL     0 NONE    0 NONE    0 NONE    0 NONE
05/01-05/10 X    0 ALL     0 ALL     0 ALL     0 ALL     0 ALL     0 ALL     0 NONE    0 ALL     0 NONE    0 NONE
05/11-05/20 X    0 ALL     0 ALL     0 ALL     0 ALL     0 ALL     1 ALL     0 ALL     1 ALL     0 NONE    1 ALL
05/21-05/30 X    0 ALL     0 ALL     0 ALL     1 ALL     0 ALL     0 ALL     0 ALL     0 ALL     0 ALL     0 ALL
05/31-06/09 X    0 ALL     0 ALL     0 ALL     0 ALL     1 ALL     0 ALL     1 ALL     0 ALL     0 ALL     0 ALL
06/10-06/19 X    0 ALL     0 ALL     0 ALL     0 ALL     0 ALL     0 ALL     1 ALL     0 ALL     0 ALL     0 ALL
06/20-06/29 X    0 ALL     0 ALL     0 ALL     0 ALL     0 ALL     0 ALL     0 ALL     0 ALL     0 ALL     1 ALL
06/30-07/09 X    0 ALL     0 ALL     0 ALL     0 ALL     0 ALL     0 ALL     0 ALL     0 ALL     0 ALL     1 ALL
07/10-07/19 X    0 ALL     0 ALL     0 ALL     0 ALL     0 ALL     0 ALL     0 ALL     0 ALL     0 ALL     0 ALL
07/20-07/29 X    0 ALL     0 ALL     0 ALL     0 ALL     0 ALL     0 ALL     0 ALL     0 ALL     0 ALL     1 ALL
07/30-08/08 X    0 ALL     0 ALL     1 ALL     0 ALL     0 ALL     1 ALL     0 ALL     0 ALL     0 ALL     1 ALL
08/09-08/18 X    0 ALL     0 ALL     0 ALL     0 ALL     0 ALL     0 ALL     1 ALL     1 ALL     0 ALL     0 ALL
08/19-08/28 X    0 ALL     0 ALL     1 ALL     0 ALL     0 ALL     0 ALL     1 ALL     1 ALL     0 ALL     0 ALL
08/29-09/07 X    0 ALL     1 ALL     0 ALL     1 ALL     0 ALL     1 ALL     0 ALL     0 ALL     0 ALL     0 ALL
09/08-09/17 X    0 ALL     0 ALL     1 ALL     0 ALL     1 ALL     1 ALL     0 ALL     0 ALL     0 ALL     0 ALL
09/18-09/27 X    0 ALL     0 ALL     0 ALL     0 ALL     1 ALL     0 ALL     0 ALL     0 ALL     0 ALL     0 ALL
09/28-10/07 X    0 ALL     1 ALL     1 ALL     1 ALL     0 ALL     2 ALL     0 ALL     0 ALL     0 ALL     0 ALL
10/08-10/17 X    0 ALL     0 ALL     1 ALL     0 ALL     1 ALL     0 PART    0 ALL     0 ALL     1 ALL     0 ALL
10/18-10/27 X    0 ALL     0 ALL     1 ALL     0 ALL     1 ALL     0 NONE    0 ALL     1 ALL     0 ALL     1 ALL
10/28-11/06 X    0 ALL     0 ALL     0 ALL     0 PART    0 ALL     0 NONE    0 NONE    0 NONE    0 PART    0 PART
11/07-11/16 X    0 ALL     0 ALL     0 PART    0 NONE    0 PART    0 NONE    0 NONE    0 NONE    0 NONE    0 NONE
11/17-11/26 X    0 ALL     0 PART    0 NONE    0 NONE    0 NONE    0 NONE    0 NONE    0 NONE    0 NONE    0 NONE
11/27-12/06 X    0 ALL     0 NONE    0 NONE    0 NONE    0 NONE    0 NONE    0 NONE    0 NONE    0 NONE    0 NONE
12/07-12/16 X    0 ALL     0 NONE    0 NONE    0 NONE    0 NONE    0 NONE    0 NONE    0 NONE    0 NONE    0 NONE
12/17-12/26 X    0 ALL     0 NONE    0 NONE    0 NONE    0 NONE    0 NONE    0 NONE    0 NONE    0 NONE    0 NONE
```

```
THE AVERAGE NUMBER OF DAYS PER 10 DAY PERIOD,THE STANDARD DEVIATION ABOUT THE MEAN,
THE NUMBER OF COMPLETE 10 DAY PERIODS,AND THE TOTAL NUMBER OF DAYS FOR EACH YEAR.
AVE=AVERAGE NO. DAYS PER 10 DAY PERIOD
SDEV=STANDARD DEVIATION
CT=COMPLETE 10 DAY PERIODS
SUM=TOTAL NUMBER OF DAYS
THE YEARS ARE PRINTED ACROSS THE TOP AND THE ABBREVIATIONS DOWN THE LEFT HAND SIDE.



          1964      1965      1966      1967      1968      1969      1970      1971      1972      1973
AVE       0.00       .10       .32       .16       .27       .35       .24       .22       .06       .35
SDEV      0.00       .31       .48       .37       .46       .61       .44       .43       .25       .49
CT       36.00     20.00     19.00     19.00     22.00     17.00     17.00     18.00     16.00     17.00
SUM       0.00      2.00      6.00      3.00      6.00      6.00      4.00      4.00      1.00      6.00
```

```
THIS TABLE SHOWS THE TOTAL NUMBER OF DAYS WHICH MET THE PRESCRIPTION IN EACH
 10 DAY PERIOD FOR THE ENTIRE  10 YEARS. ALSO COMPUTED ARE THE MEAN NUMBER OF DAYS/YEAR IN EACH
 PERIOD. AND THE STANDARD DEVIATION. 10 DAY PERIODS ARE PRINTED DOWN THE
 LEFT HAND SIDE WHILE SUM. AVERAGE, AND STANDARD  DEVIATION ARE ACRCSS THE TOP.


                         SUM                           AVE                          STD. DEV.
XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
01/01-01/10 X            0.00                          0.00                           0.00
01/11-01/20 X            0.00                          0.00                           0.00
01/21-01/30 X            0.00                          0.00                           0.00
01/31-02/09 X            0.00                          0.00                           0.00
02/10-02/19 X            0.00                          0.00                           0.00
02/20-03/01 X            0.00                          0.00                           0.00
03/02-03/11 X            0.00                          0.00                           0.00
03/12-03/21 X            0.00                          0.00                           0.00
03/22-03/31 X            0.00                          0.00                           0.00
04/01-04/10 X            0.00                          0.00                           0.00
04/11-04/20 X            1.00                           .10                            .32
04/21-04/30 X            0.00                          0.00                           0.00
05/01-05/10 X            0.00                          0.00                           0.00
05/11-05/20 X            3.00                           .30                            .48
05/21-05/30 X            1.00                           .10                            .32
05/31-06/09 X            2.00                           .20                            .42
06/10-06/19 X            1.00                           .10                            .32
06/20-06/29 X            1.00                           .10                            .32
06/30-07/09 X            1.00                           .10                            .32
07/10-07/19 X            0.00                          0.00                           0.00
07/20-07/29 X            1.00                           .10                            .32
07/30-08/08 X            3.00                           .30                            .48
08/09-08/18 X            2.00                           .20                            .42
08/19-08/28 X            3.00                           .30                            .48
08/29-09/07 X            3.00                           .30                            .48
09/08-09/17 X            3.00                           .30                            .48
09/18-09/27 X            1.00                           .10                            .32
09/28-10/07 X            5.00                           .50                            .71
10/08-10/17 X            3.00                           .30                            .48
10/18-10/27 X            4.00                           .40                            .52
10/28-11/06 X            0.00                          0.00                           0.00
11/07-11/16 X            0.00                          0.00                           0.00
11/17-11/26 X            0.00                          0.00                           0.00
11/27-12/06 X            0.00                          0.00                           0.00
12/07-12/16 X            0.00                          0.00                           0.00
12/17-12/26 X            0.00                          0.00                           0.00
```

Appendix C

Appendix C contains graphs of the total number of days for each 10 day period for the entire 10 years. Number of days are along the left hand side, and 10 day periods are listed along the bottom. The prescription is given in the upper left hand corner. Symbols used are:

BI = Burning Index
TEMP = Temperature
RH = Relative Humidity
WS = Wind Speed
FM = Fuel Moisture
HR = Hour

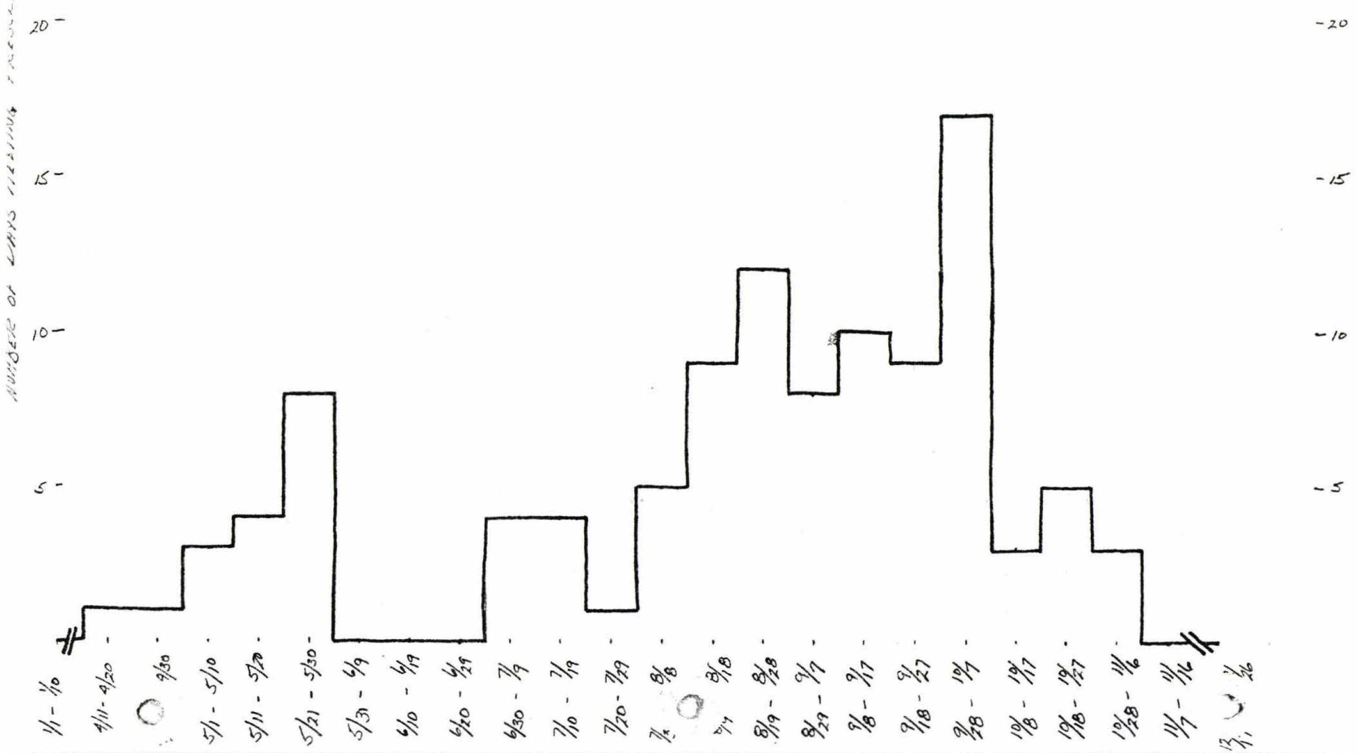
Reading the graph is relatively simple. For example: Nemo A-2 the 10 day period 9/28-10/7 had a total of 17 days meet the prescription given over the entire 10 years. This could be interpreted as indicating that 9/28-10/7 is more likely to meet those given prescription parameters than the period 7/20-7/29 which had only 1 day in 10 years which met the prescription.

This appendix contains a graph for each prescription used in each fuel model type for each station. These graphs may be used to determine a burning program, and possible prescriptions.

NOTE: Some graphs that have broken lines and contain a small number in parentheses ( ) above the 10 day period indicate how many 10 day periods are in that broken line segment.

NEMO A-2

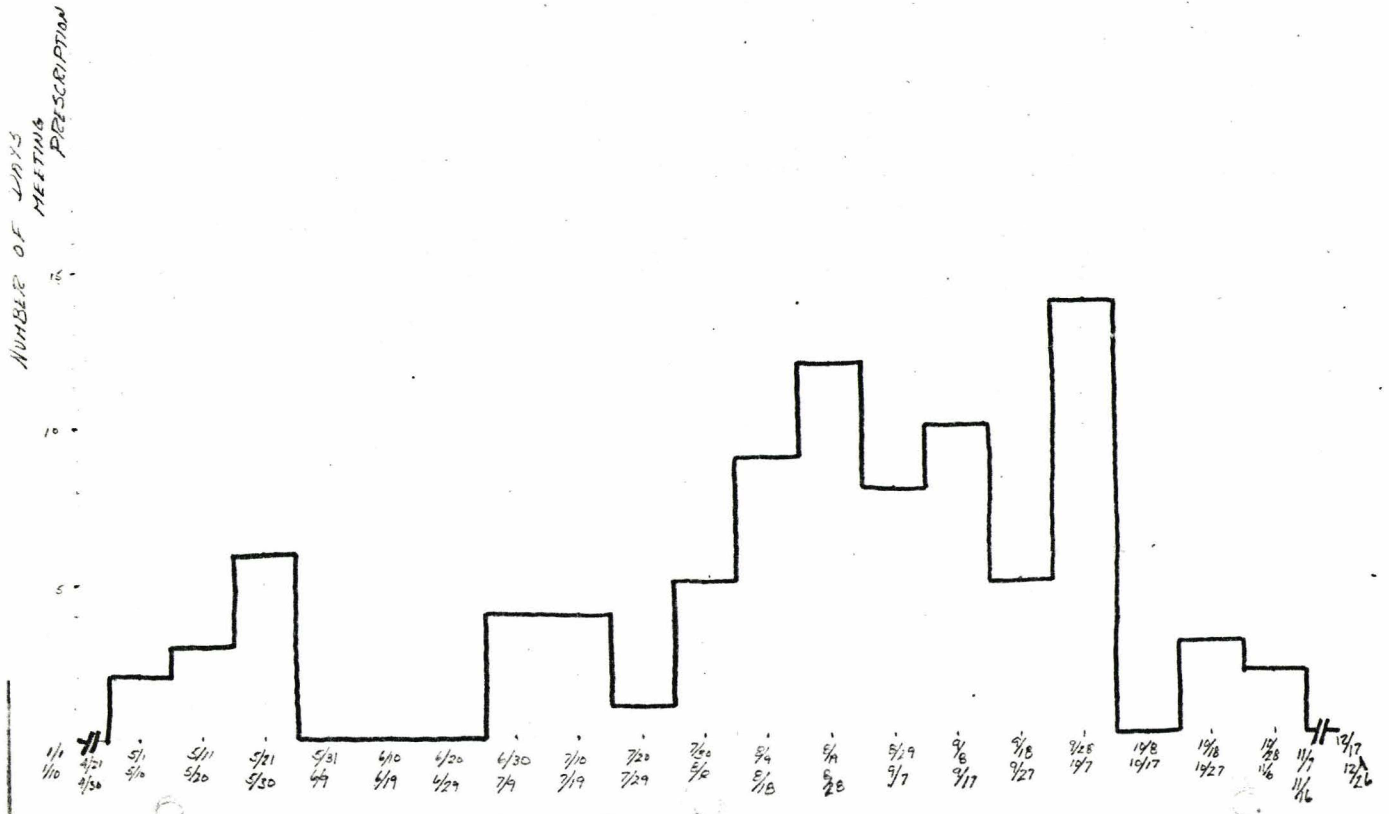
BI 0-12
TEMP 65-90
RH 10-25
WS 5-12
1 HR FM 0-12



NEMO A

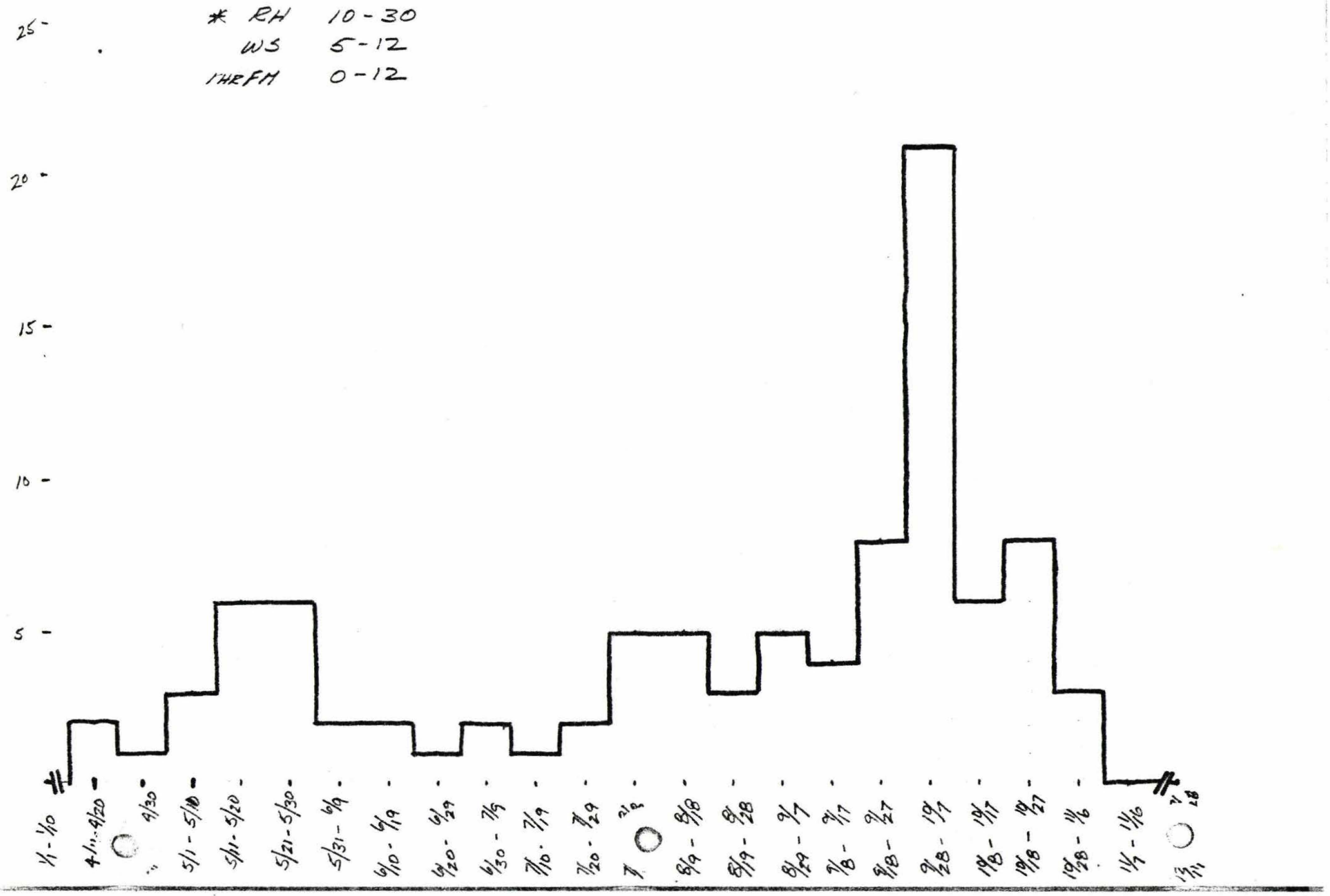
TOTAL NUMBER OF DAYS IN EACH
10 DAY PERIOD - FOR 10 YEARS

BI 0-12
TEMP 70-90
RH 10-25
WS 5-12
1 HR FM 0-12



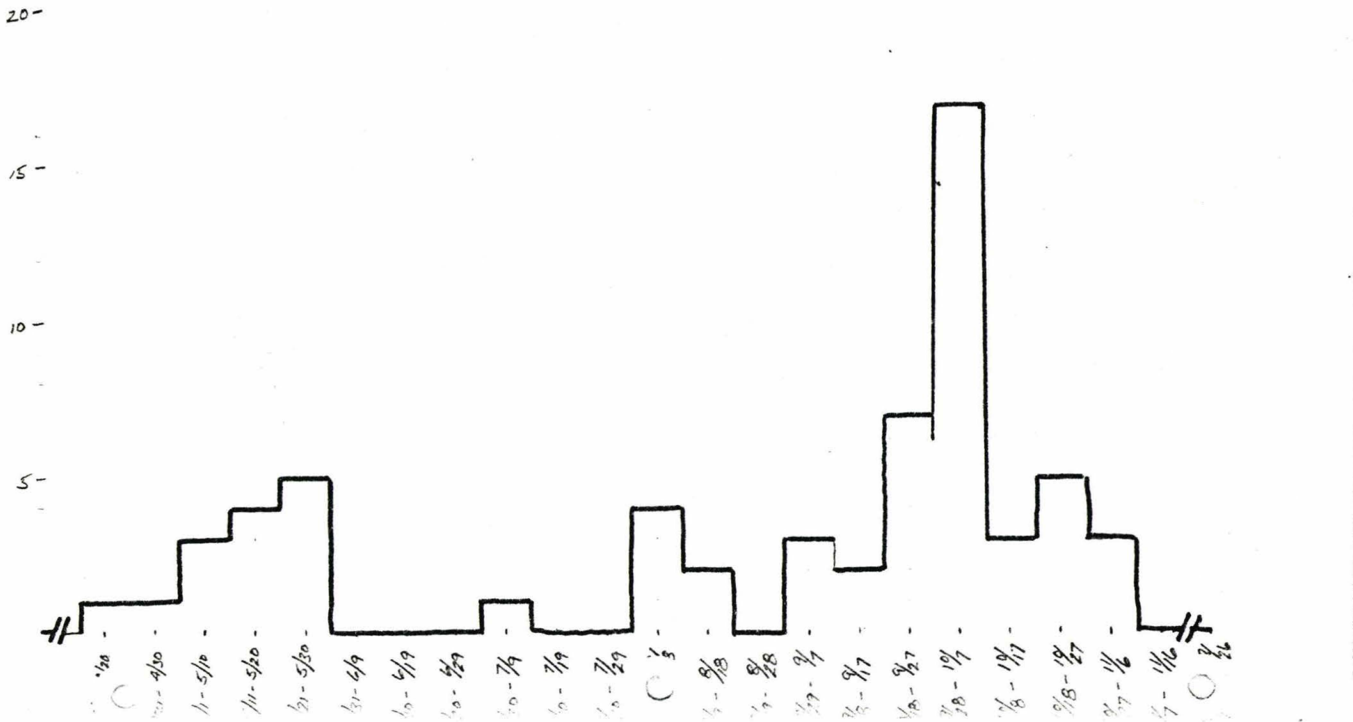
NEMO A-4

BI 0-12
TEMP 65-80
* RH 10-30
WS 5-12
1HR FM 0-12



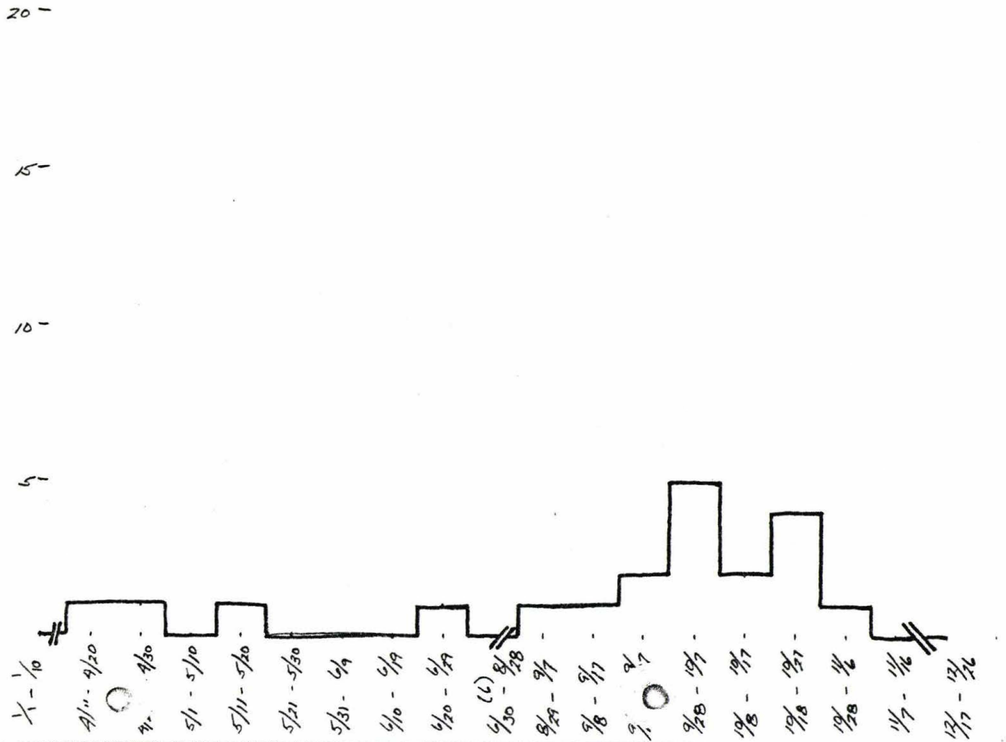
NEMO A-3 TOTAL NUMBER OF DAYS IN EACH 10 DAY PERIOD - FOR 10 YEARS

BI 0-12
* TEMP 65-80
RH 10-25
WS 5-12
* 1HR FM 0-12 - LIMIT 12 IS THE HIGH
ABOVE THAT = 0 DAYS



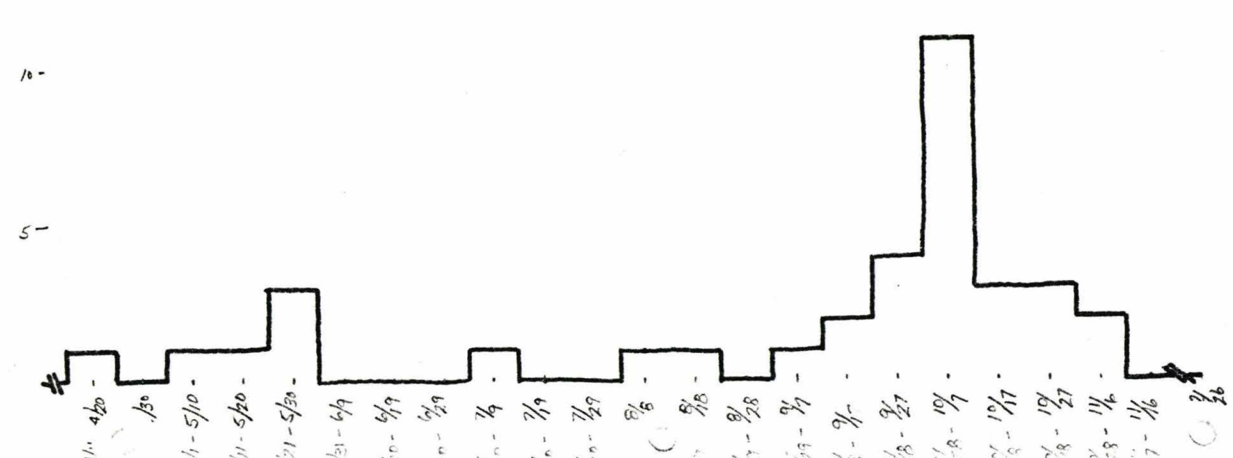
NEMO A-6

BI 0-12
TEMP 65-80
RH 0-15
WS 5-12
1 HR FM 0-12



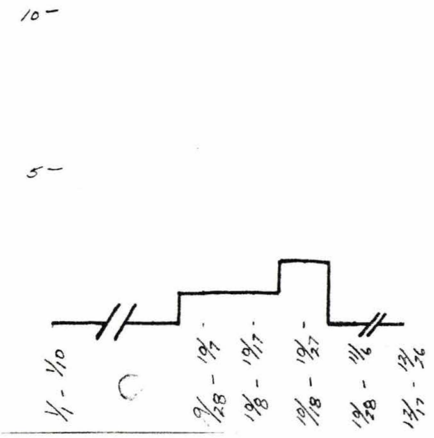
NEMO A-5

BI 0-12
TEMP 65-80
* RH 10-20
WS 5-12
1 HR FM 0-12



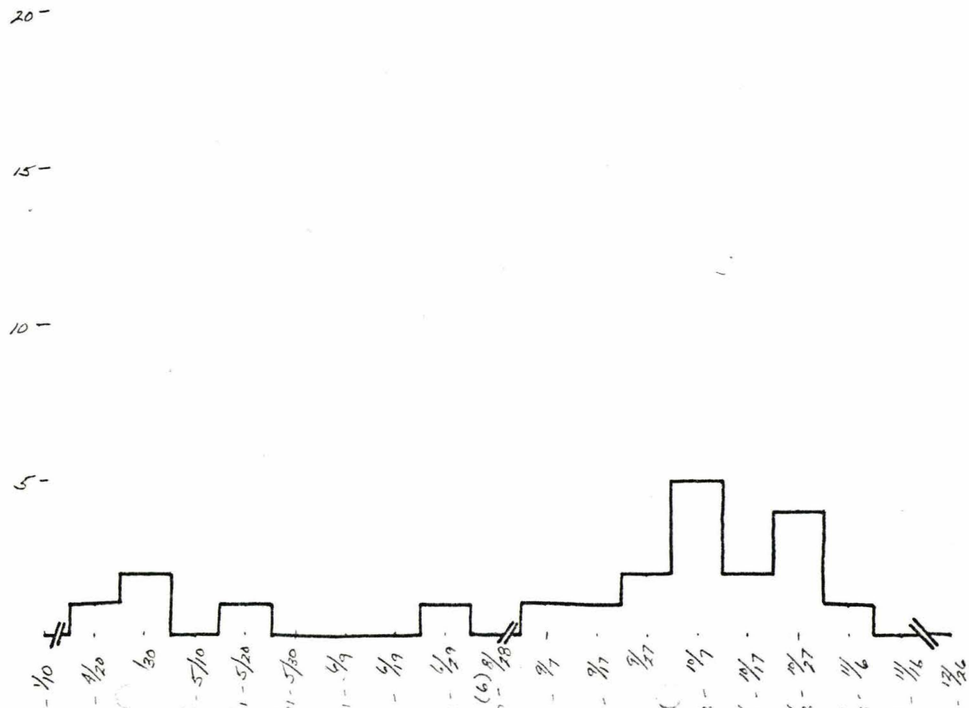
NEMO A - 8

BI 0-12
TEMP 40-65
RH 0-15
WS 5-15
1HR FM 0-12



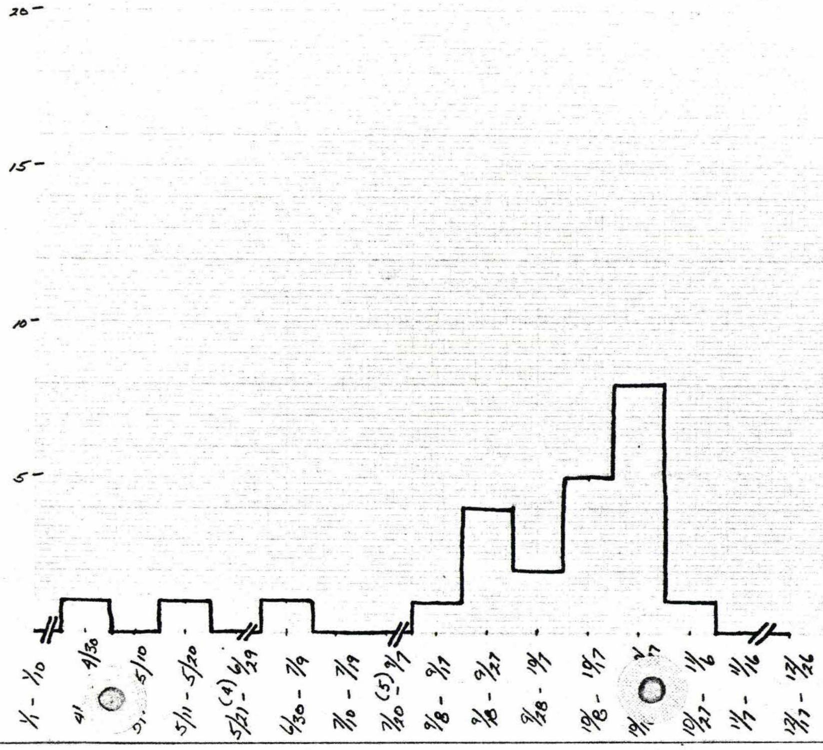
NEMO A-7

BI 0-12
TEMP 65 - 80
RH 0-15
WS 5-15
1HR FM 0-12



NEMO A-10

BI 0-12
TEMP 40-65
* RH 10-30
WS 5-15
1HR FM 5-15



NEMO A-9

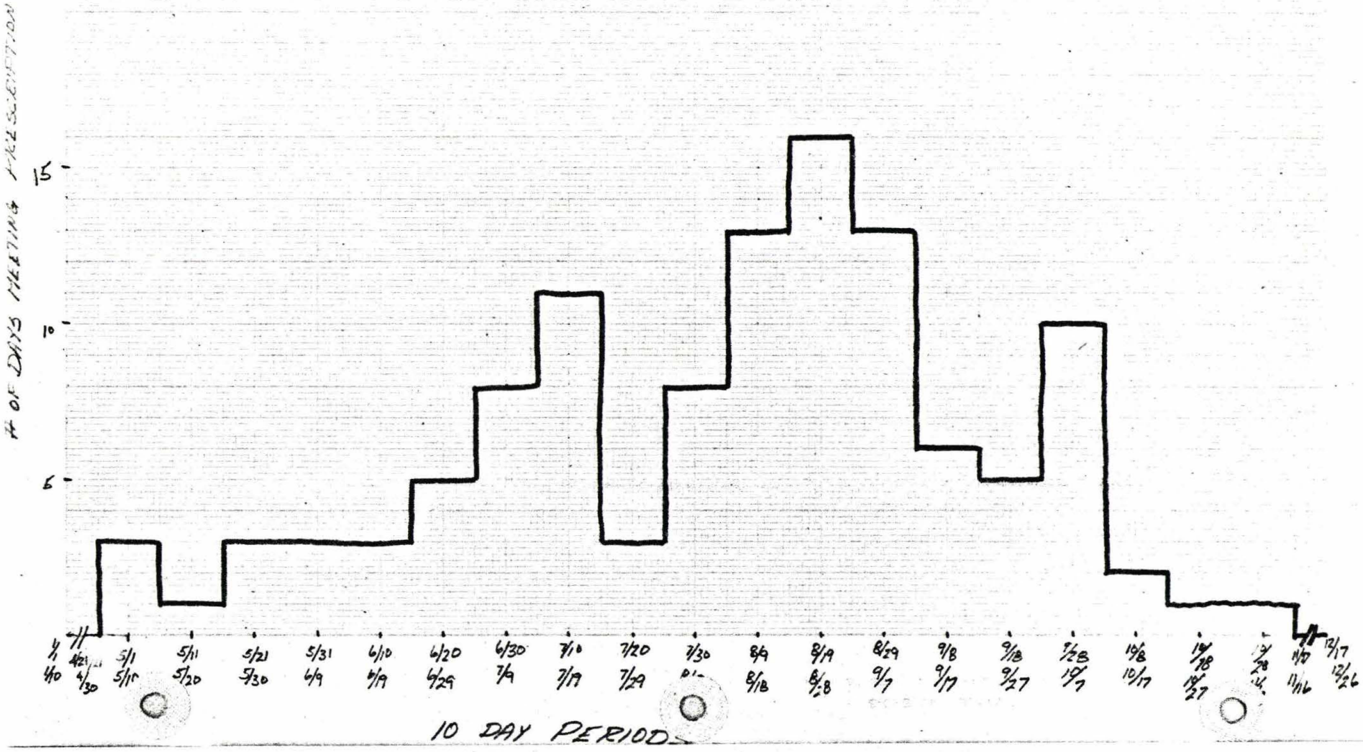
BI 0-12
TEMP 40-65
RH 0-15
WS 5-15
* 1HR FM 5-15

NO DAYS

TEPEE A

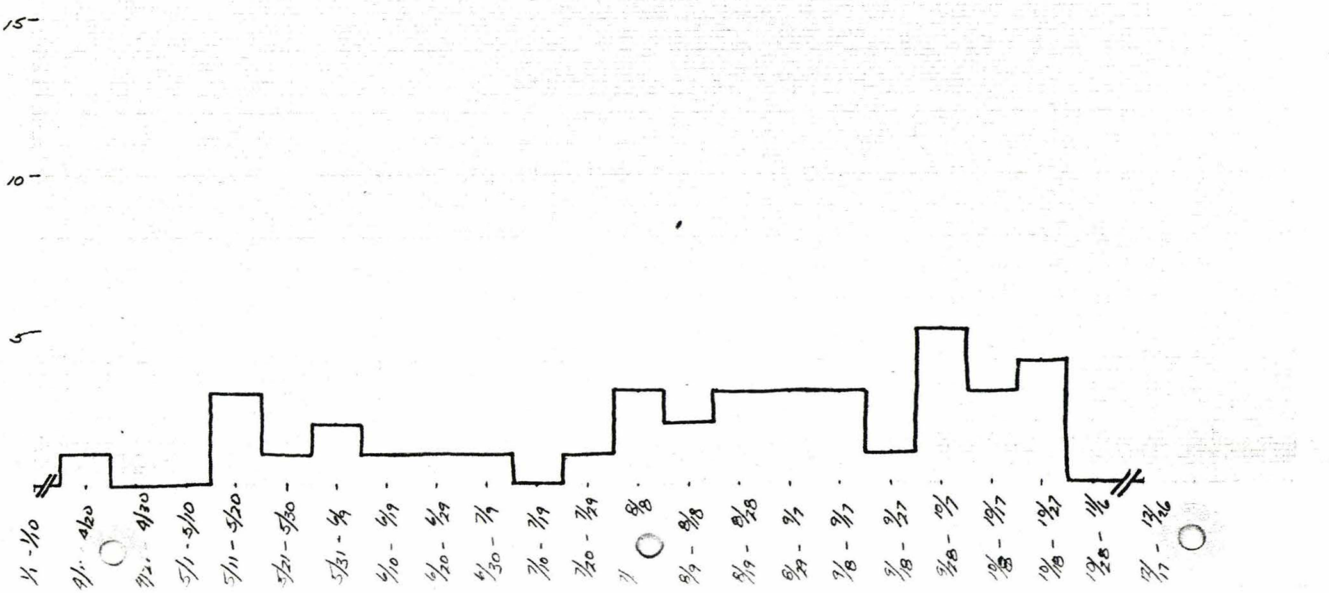
BI 0-12
TEMP 70-90
RH 10-25
WS 5-12
ADJ FM 0-12

6.10 % OF THE DAYS RECORDED



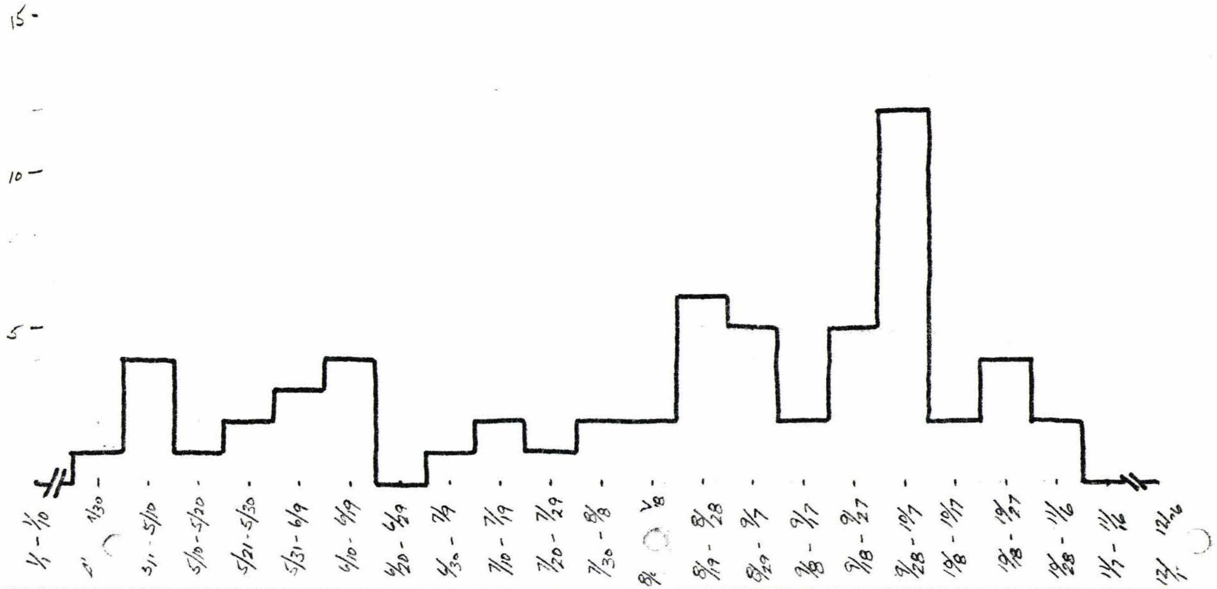
NEMO A-11

BI 0-12
* TEMP 65-80
RH 10-30
WS 5-15
1HR FM 5-15



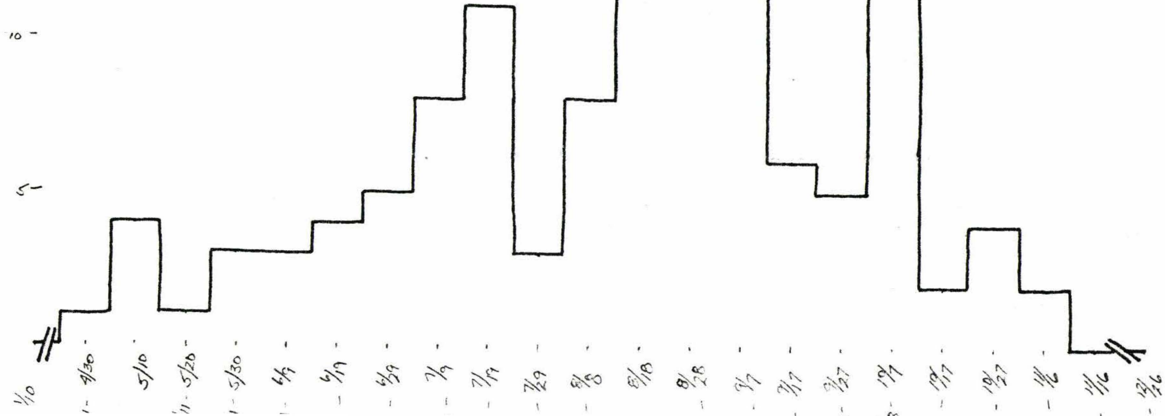
TEPEE A-3

BI	0-12
* TEMP	65-80
RH	10-25
WS	5-12
FFM	0-12



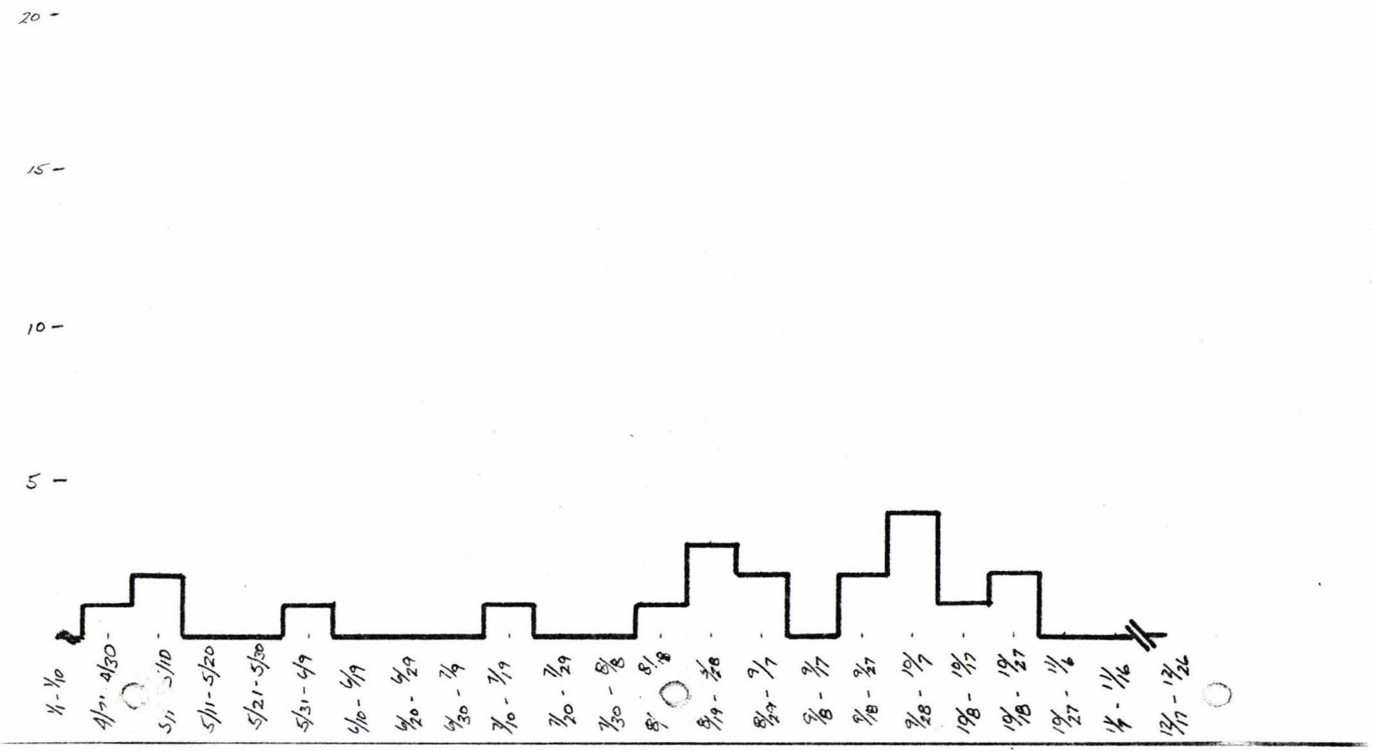
TEPEE A-2

BI	0-12
TEMP	65-90
RH	10-25
WS	5-12
FFM	0-12



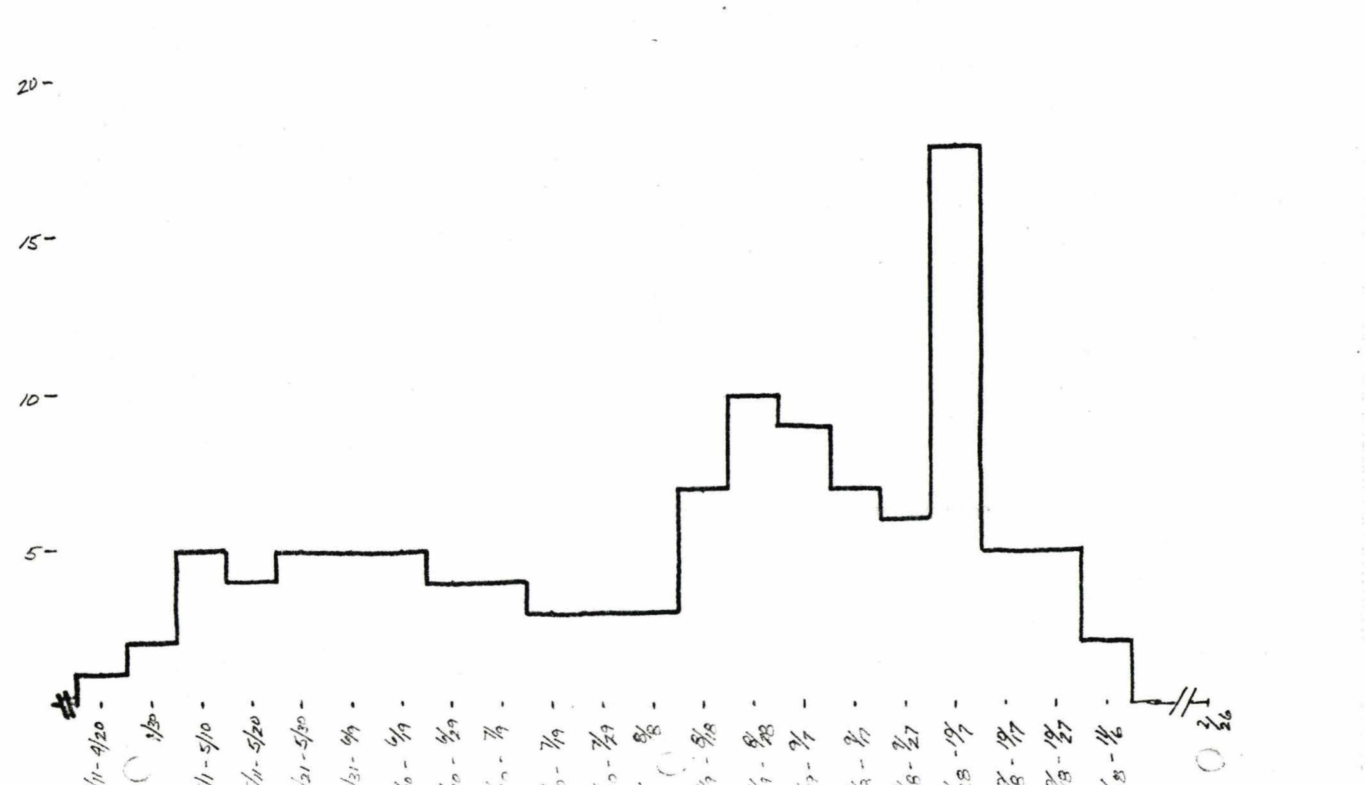
TEPEE A-5

BI 0-12
TEMP 65-80
* RH 10-20
WS 5-12
FFM 0-12



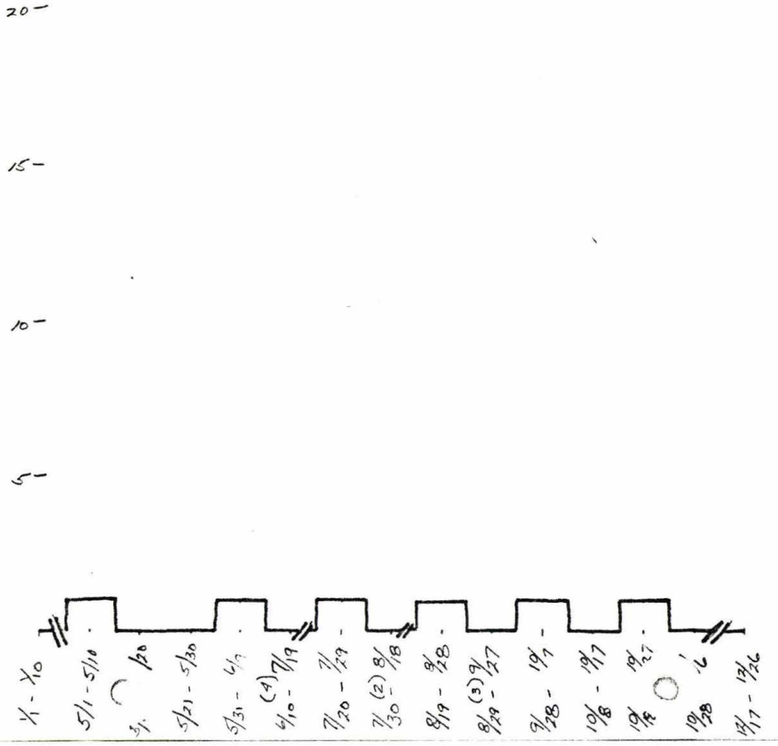
TEPEE A-4

BI 0-12
TEMP 65-80
* RH 10-30
WS 5-12
FFM 0-12



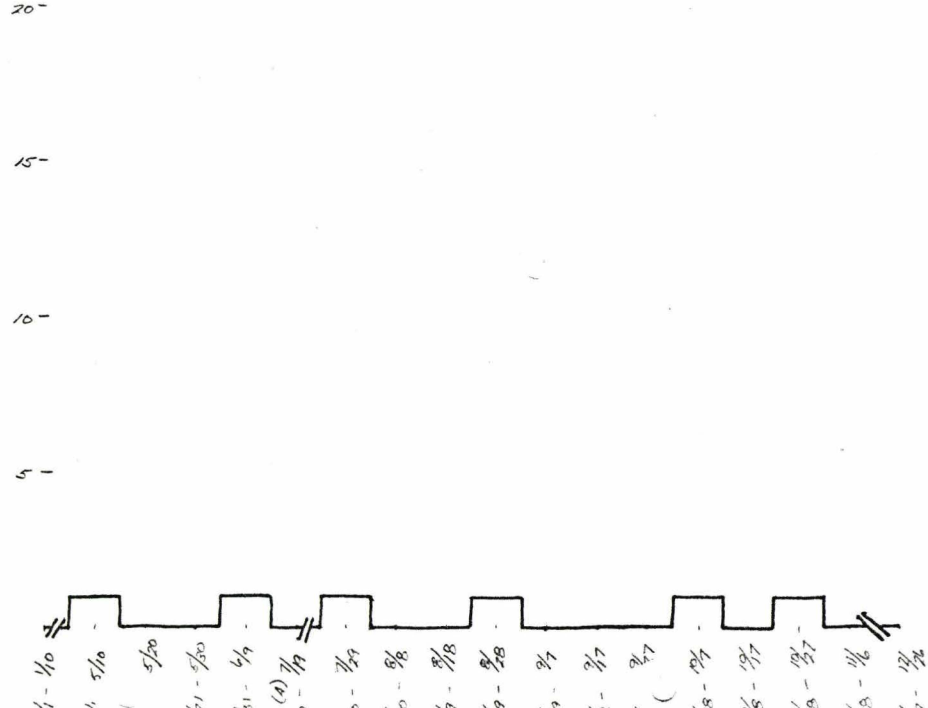
TEPEE A-7

BI 0-12
TEMP 65-80
RH 0-15
WS 5-12
1HR FM 0-12



TEPEE A-6

BI 0-12
TEMP 65-80
RH 0-15
WS 5-12
1HR FM 0-12



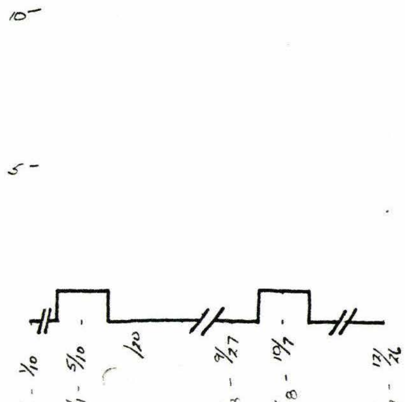
TEPEE A-9

BI 0-12
TEMP 40-65
RH 0-15
WS 5-15
* 1 HR FM 5-15

NO DAYS

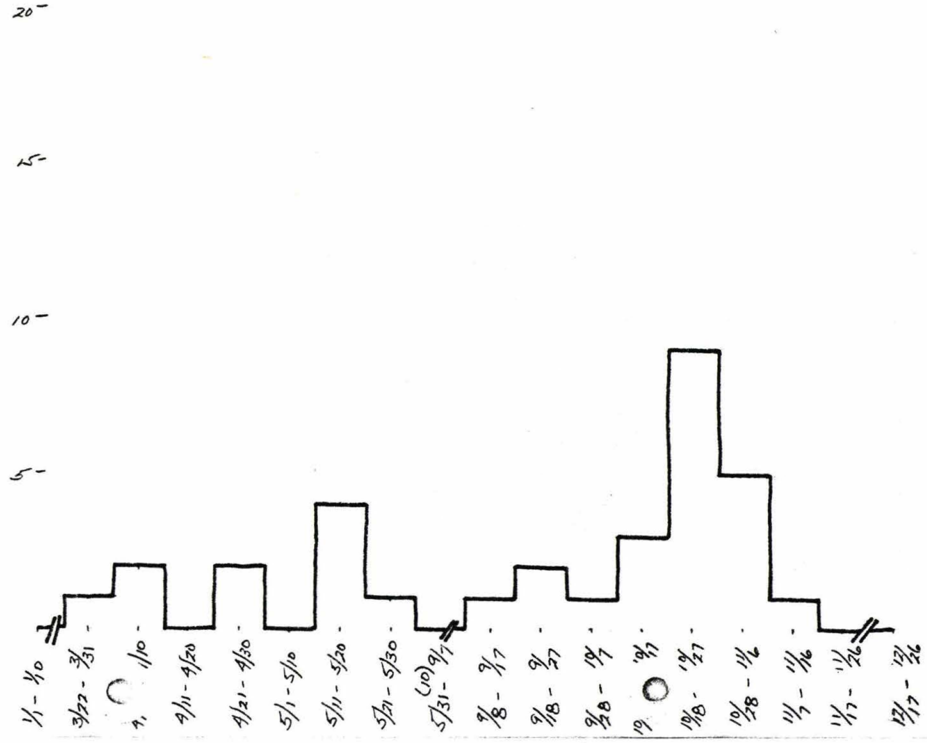
TEPEE A-8

BI 0-12
TEMP 40-65
RH 0-15
WS 5-15
1 HR FM 0-12



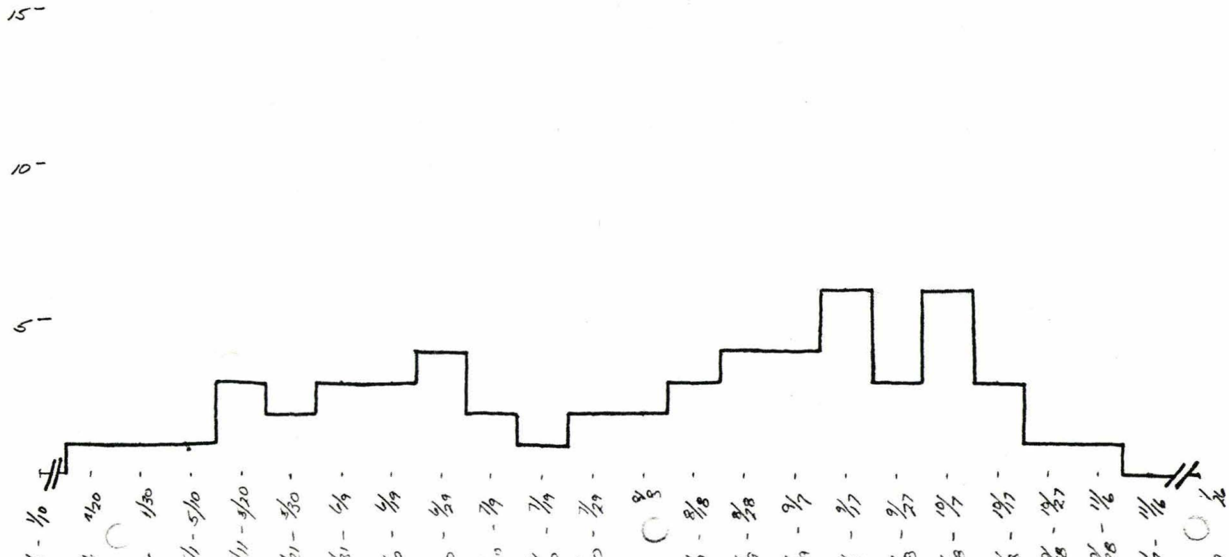
TEPEE A-10

BI 0-12
TEMP 40-65
* RH 10-30
WS 5-15
1HR FM 5-15



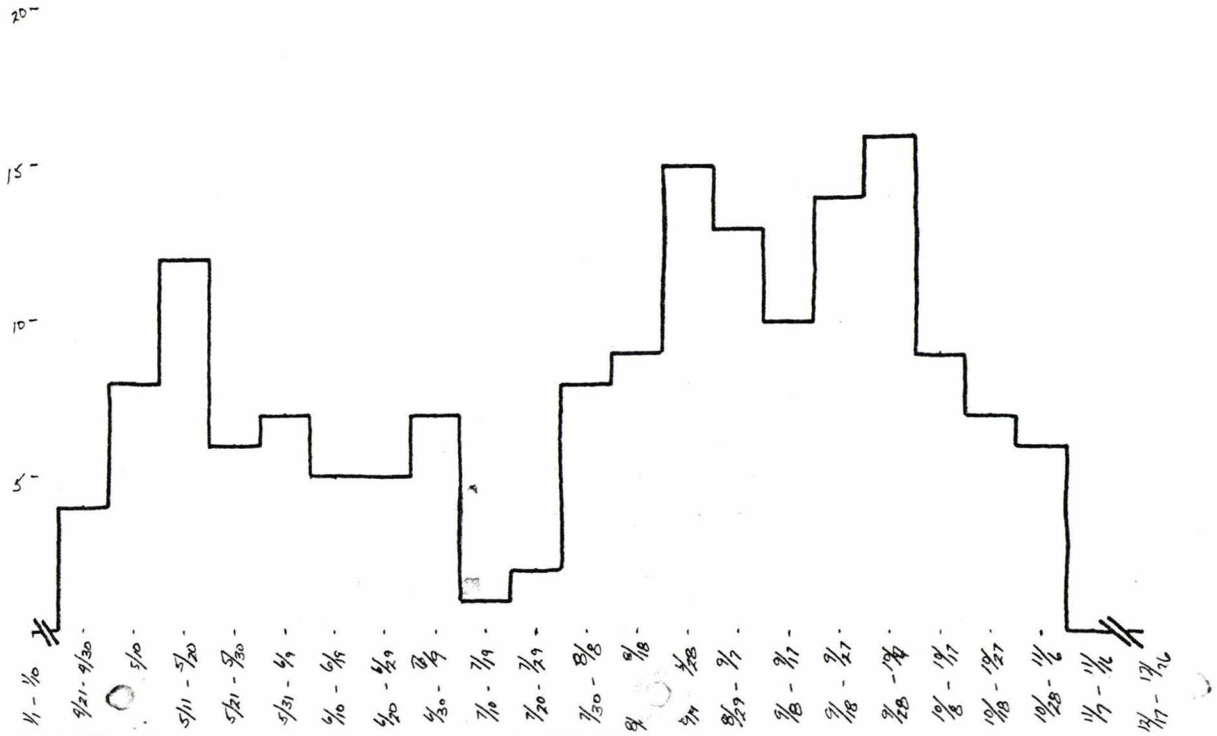
TEPEE A-11

BI 0-12
* TEMP 65-80
RH 10-30
WS 5-15
1HR FM 5-15



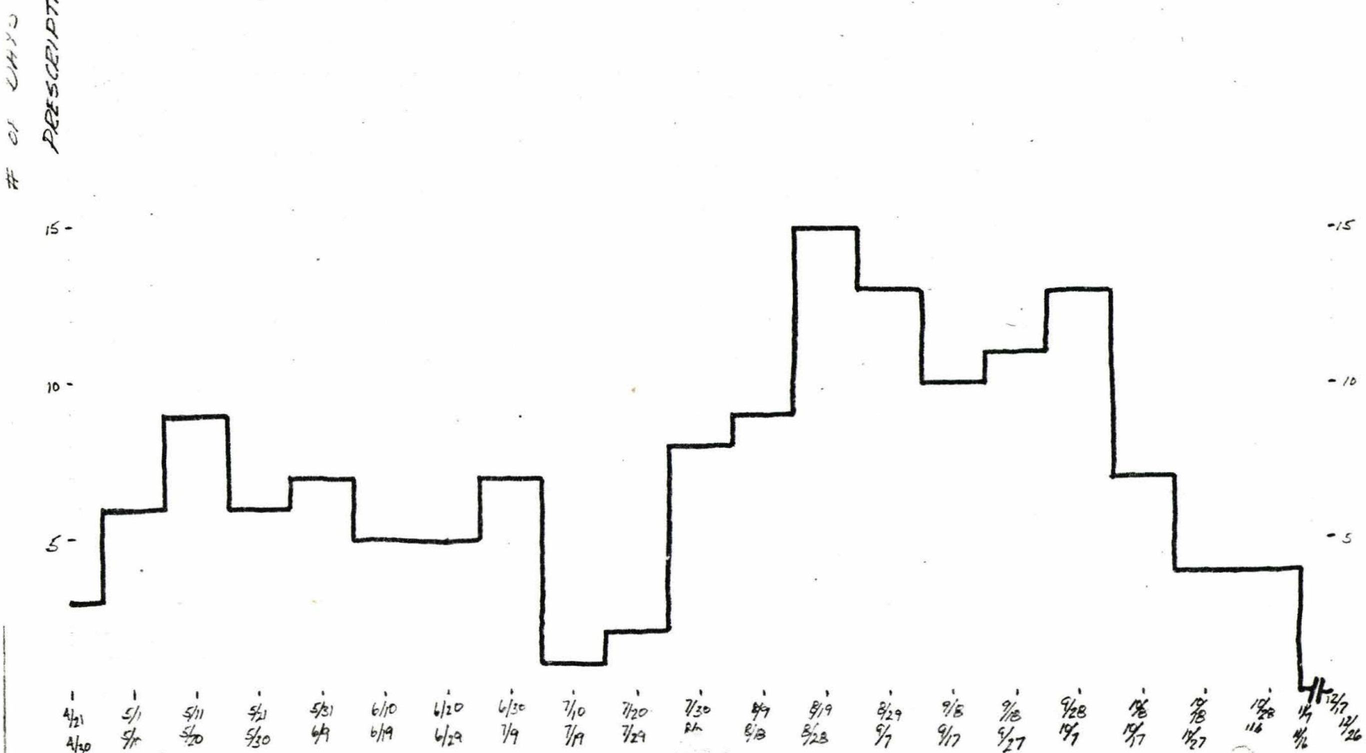
HOT SPRINGS A-2

BI 0-12
TEMP 65-90
RH 10-25
WS 5-12
FFM 0-12



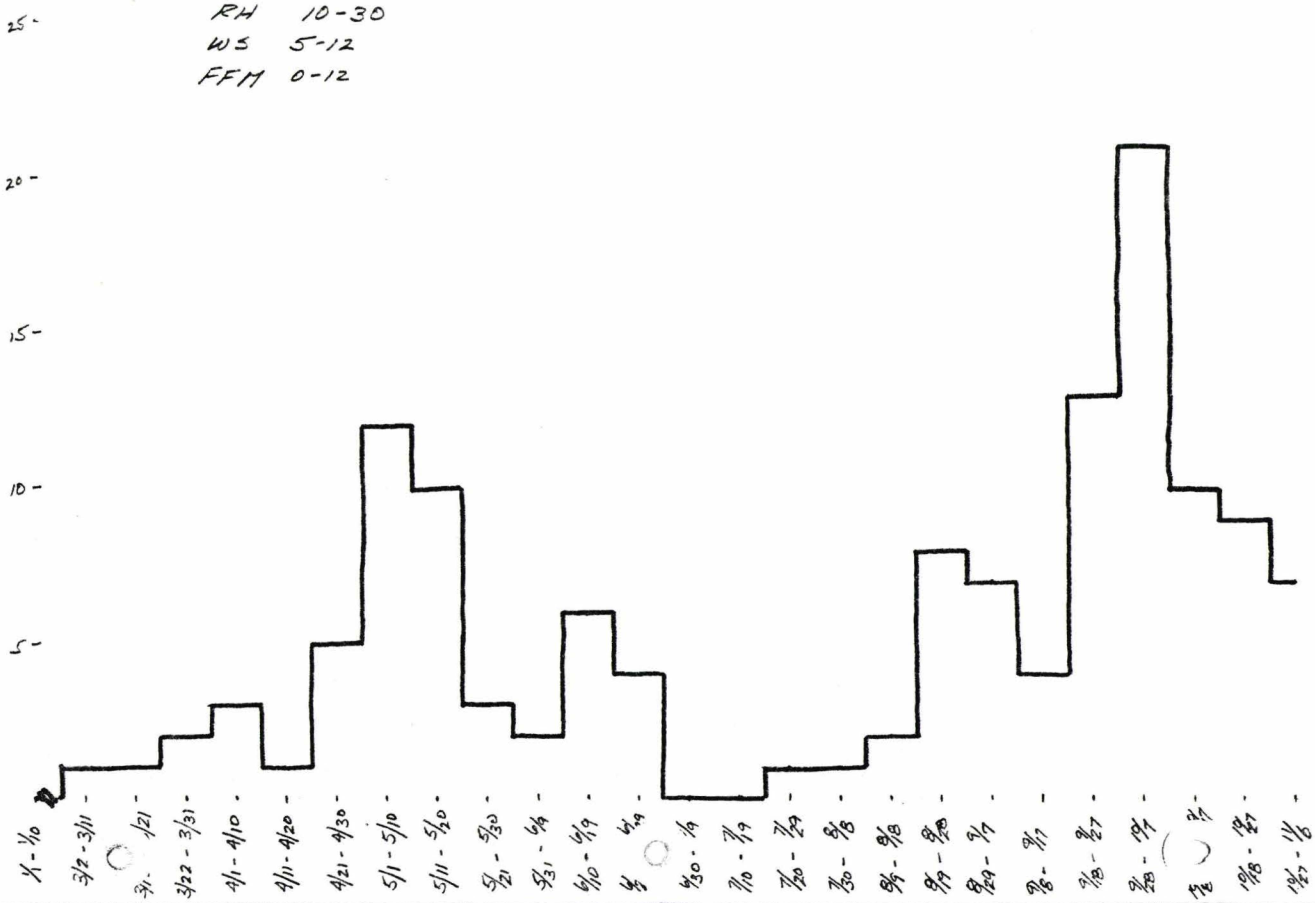
HOT SPRINGS A

BI 0-12
TEMP 70-90
RH 10-25
WS 5-12
1HR FM 0-12



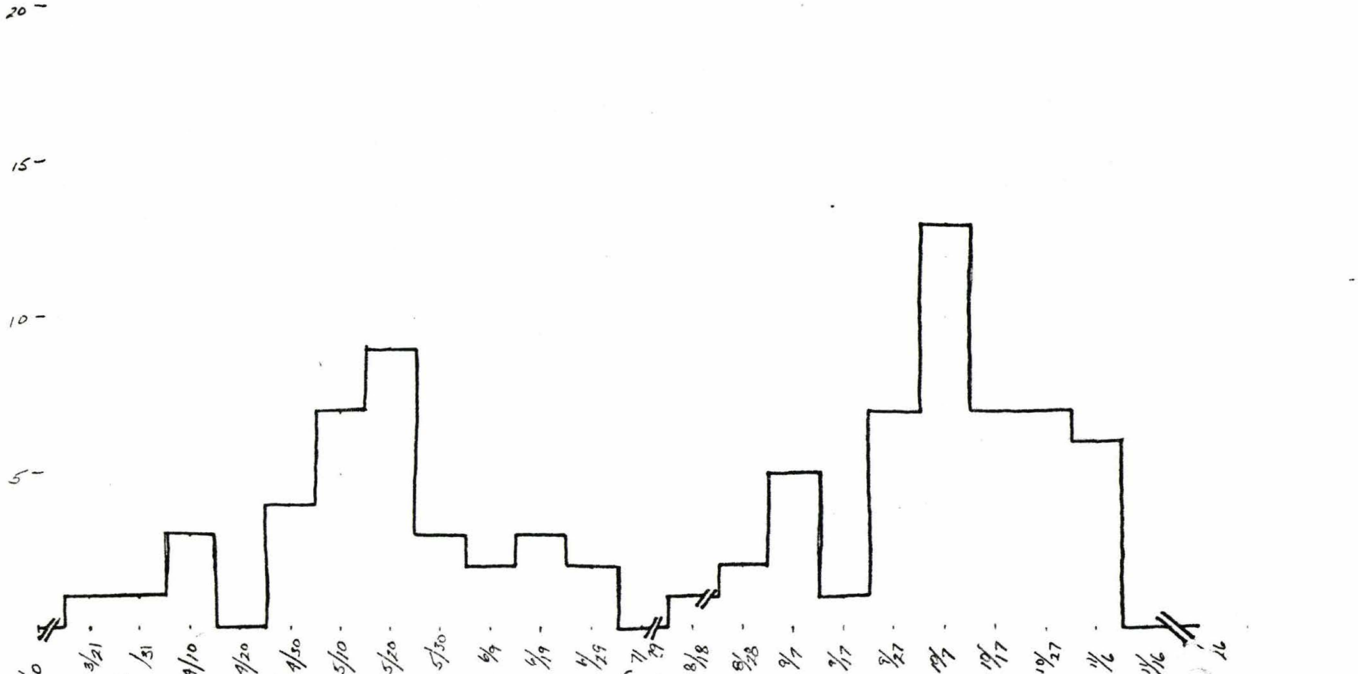
HOT SPRINGS A-4

BI 0-12
TEMP 65-80
RH 10-30
WS 5-12
FFM 0-12



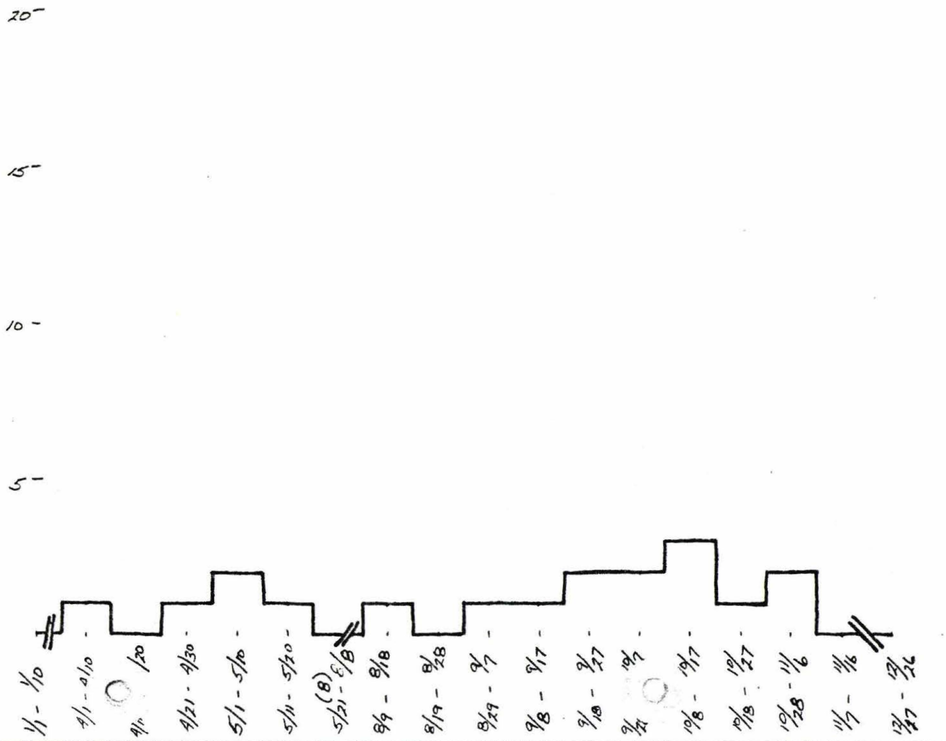
HOT SPRINGS A-3

BI 0-12
TEMP 65-80
RH 10-25
WS 5-12
1HR FM 0-12



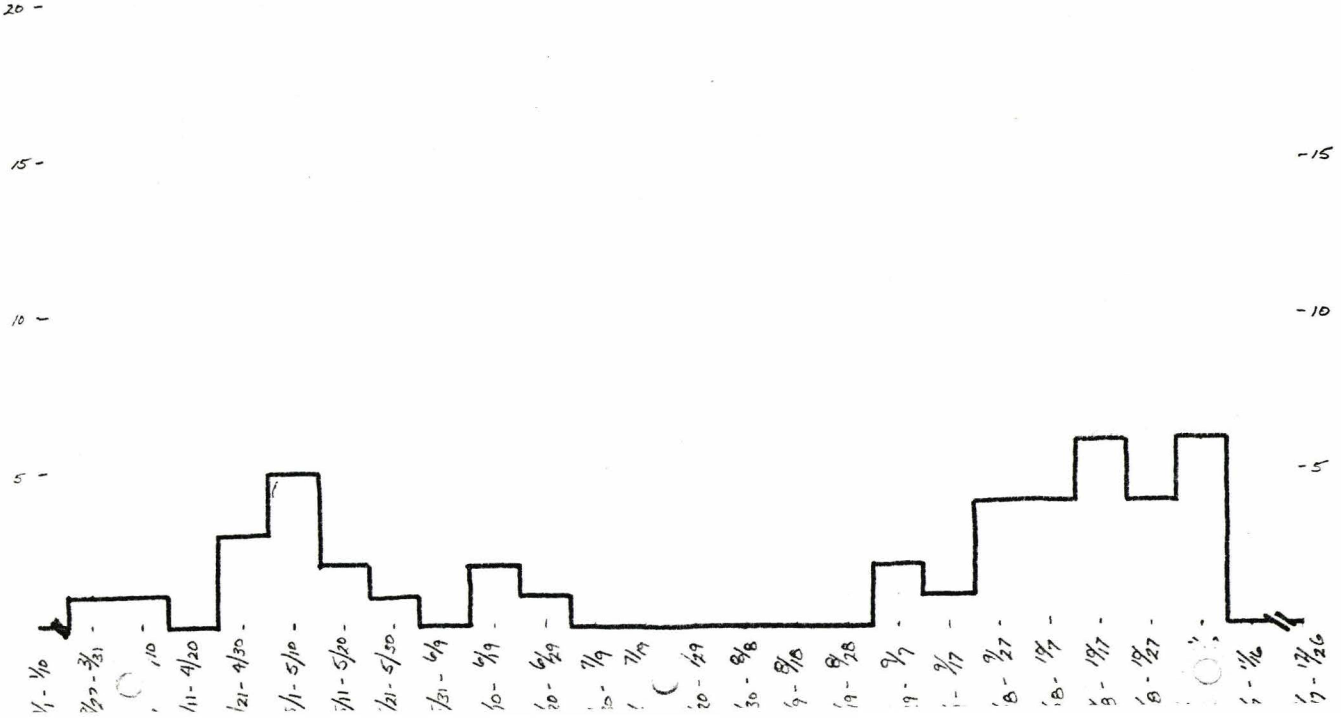
HOT SPRINGS A-6

BI 0-12
TEMP 65-80
RH 0-15
WS 5-12
1HR FM 0-12



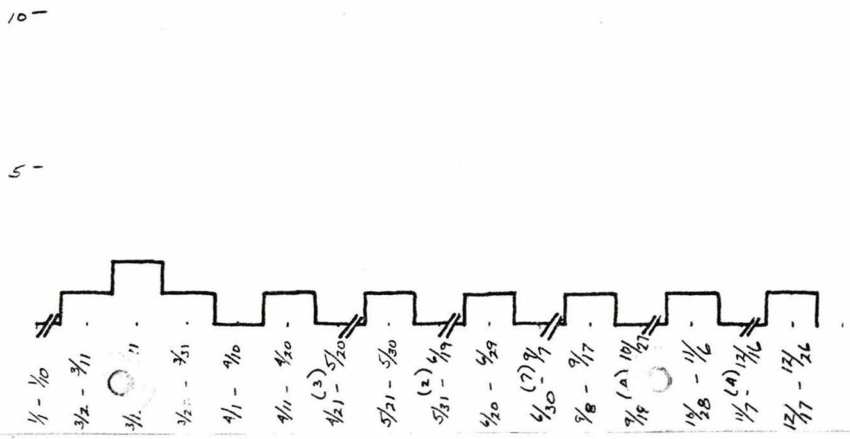
HOT SPRINGS A-5

BI 0-12
TEMP 65-80
* RH 10-20
WS 5-12
FFM 0-12



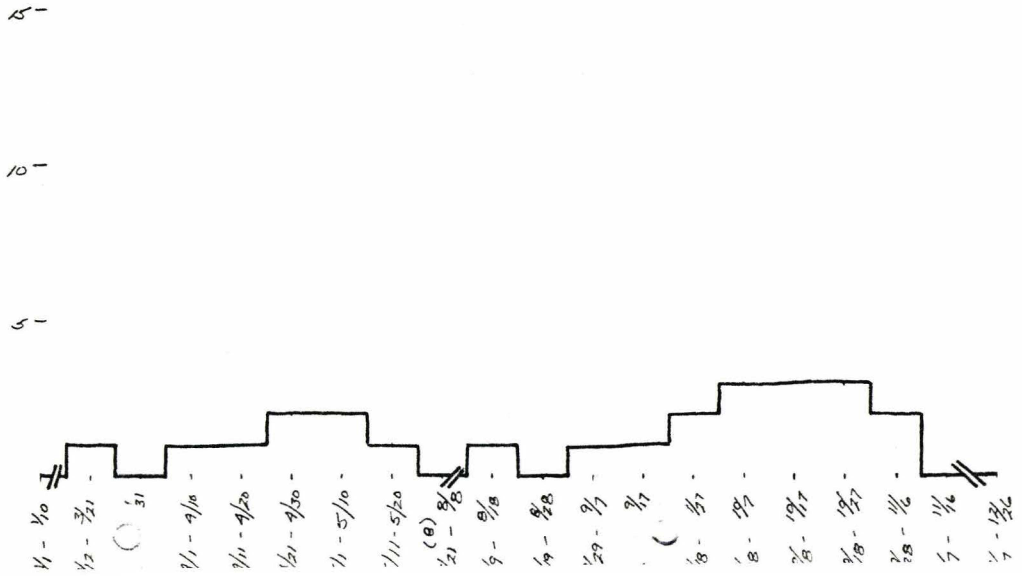
HOT SPRINGS A-8

BI 0-12
TEMP 40-65
RH 0-15
WS 5-15
1HR FM 0-12



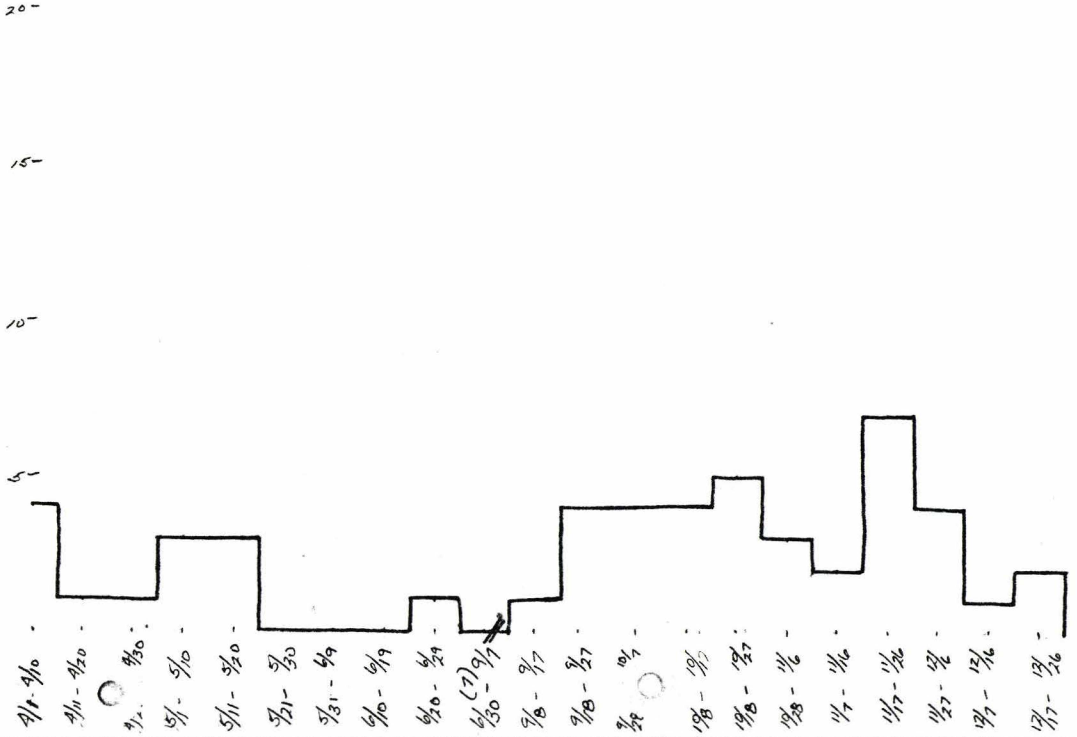
HOT SPRINGS A-7

BI 0-12
TEMP 65-80
RH 0-15
WS 5-12
1HR FM 0-12



HOT SPRINGS A-10

BI 0-12
TEMP 40-65
* RH 10-30
WS 5-15
1HR FM 5-15



HOT SPRINGS A-9

BI 0-12
TEMP 40-65
RH 0-15
WS 5-15
* 1HR FM 5-15

NO DAYS

CHEY CROSSING C-1

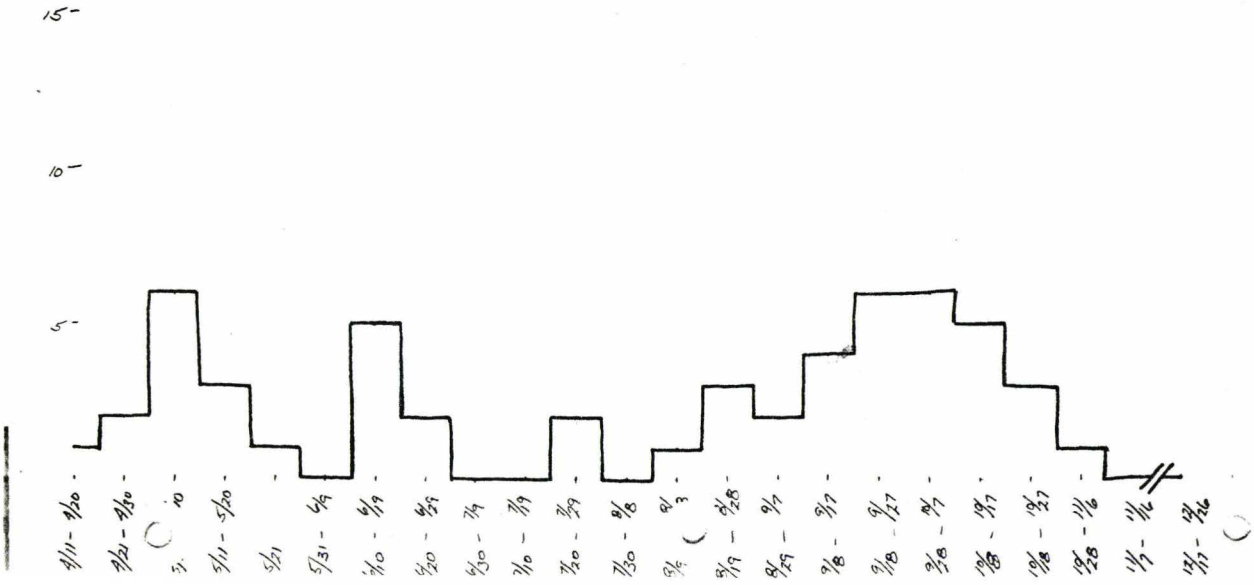
BI 0-30
TEMP 65-85
RH 15-50
WS 5-10
1 HR FM 10-25
10 HR FM 10-30

NUMBER OF DAYS MEETING PRESCRIPTION

NO DAYS

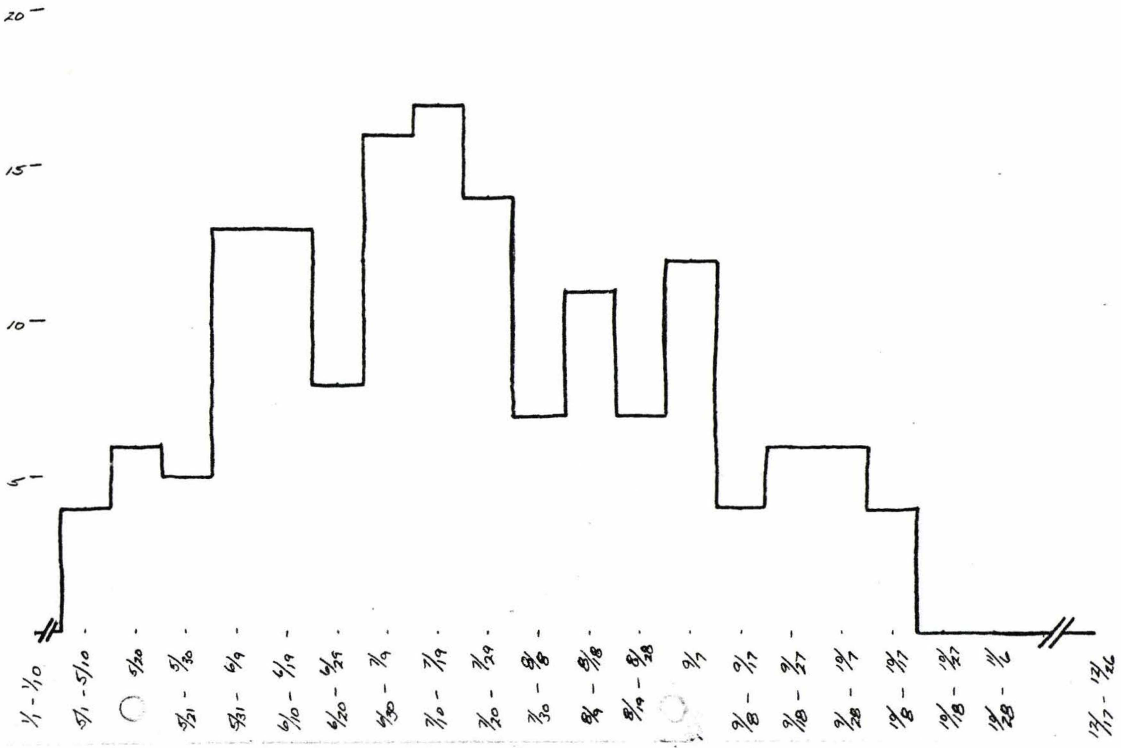
HOT SPRINGS A-11

BI 0-12
* TEMP 65-80
RH 10-30
WS 5-15
1 HR FM 5-15



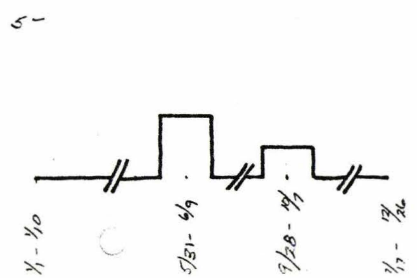
CHEY CROSS C-3

BI 0-30
TEMP 65-85
RH 15-50
WS 5-10
1 HR FM 5-30
*10 HR FM 5-30



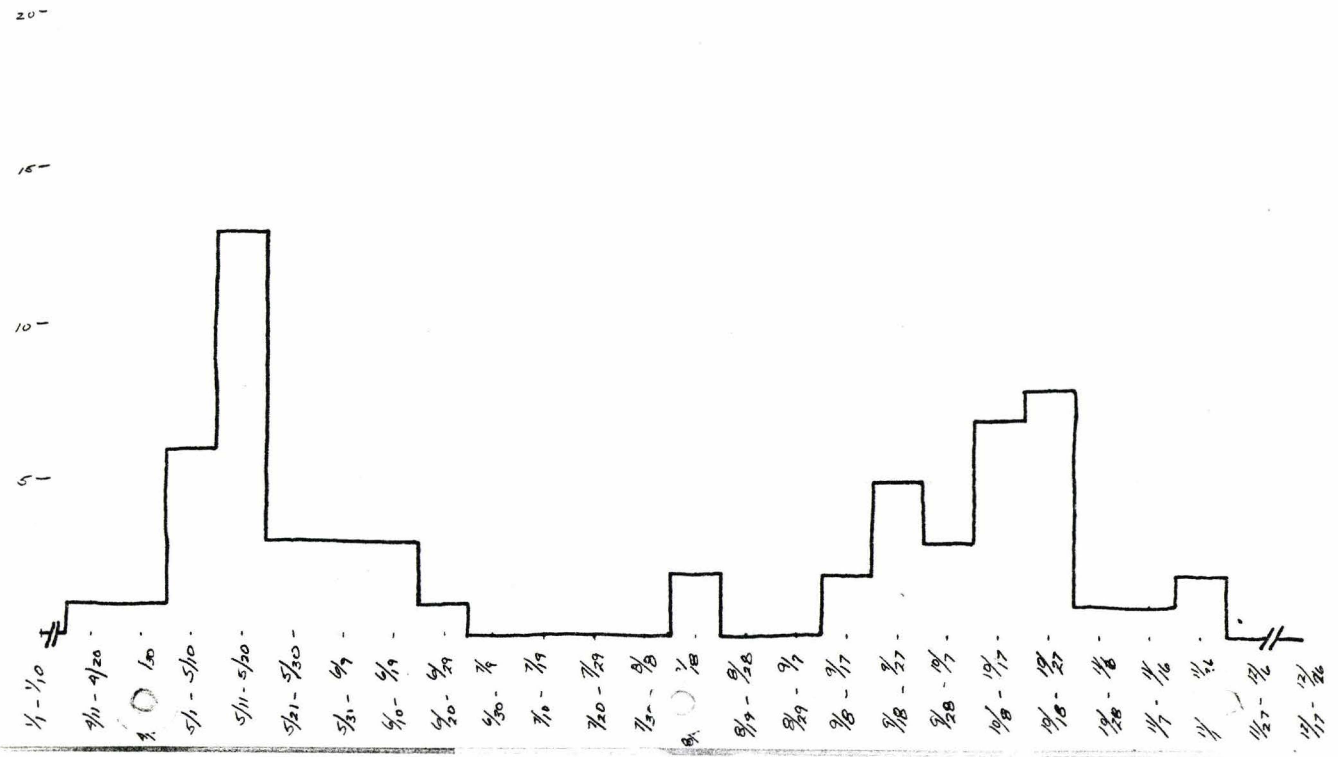
CHEY CROSS C-2

BI 0-30
TEMP 65-85
RH 15-50
WS 5-10
*1HR FM 5-30
10 HR FM 10-30



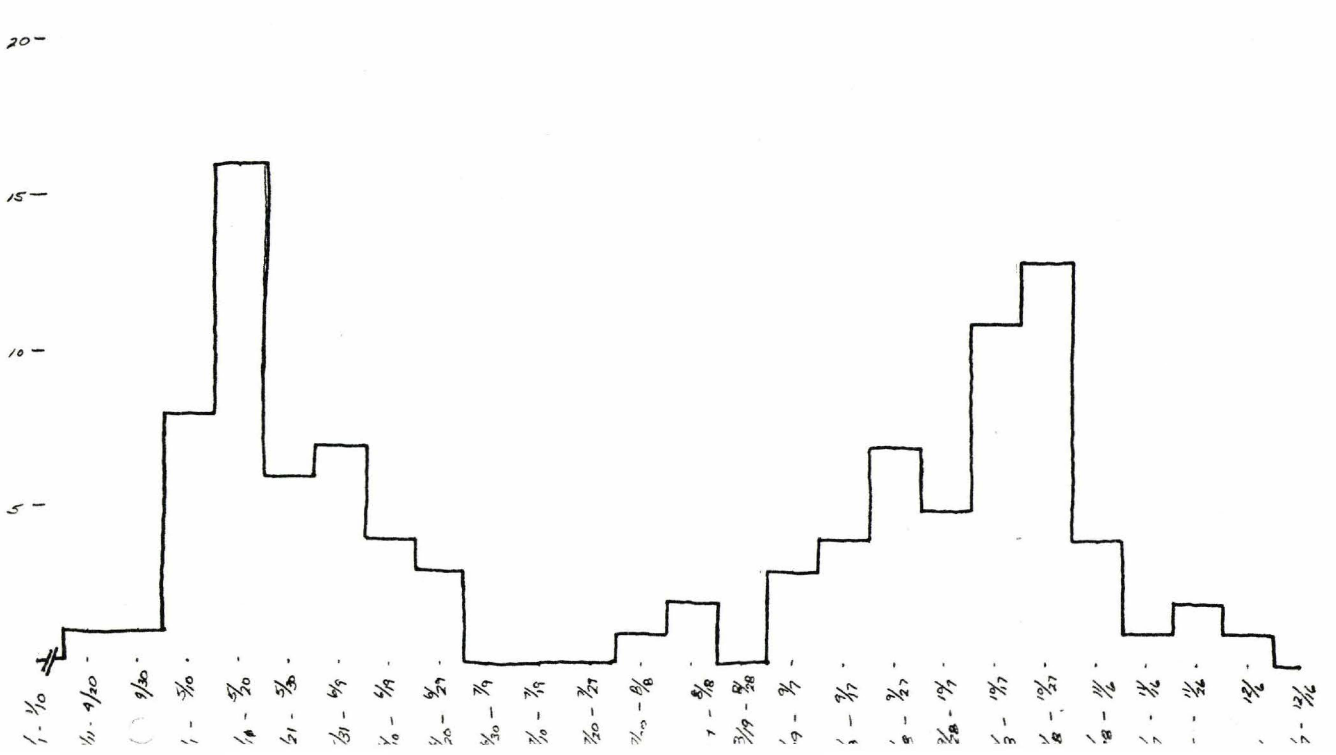
CHEY CROSS C-5

BI 0-30
TEMP 40-65
RH 15-40
WS 5-10
1 HR FM 5-30
10 HR FM 5-30



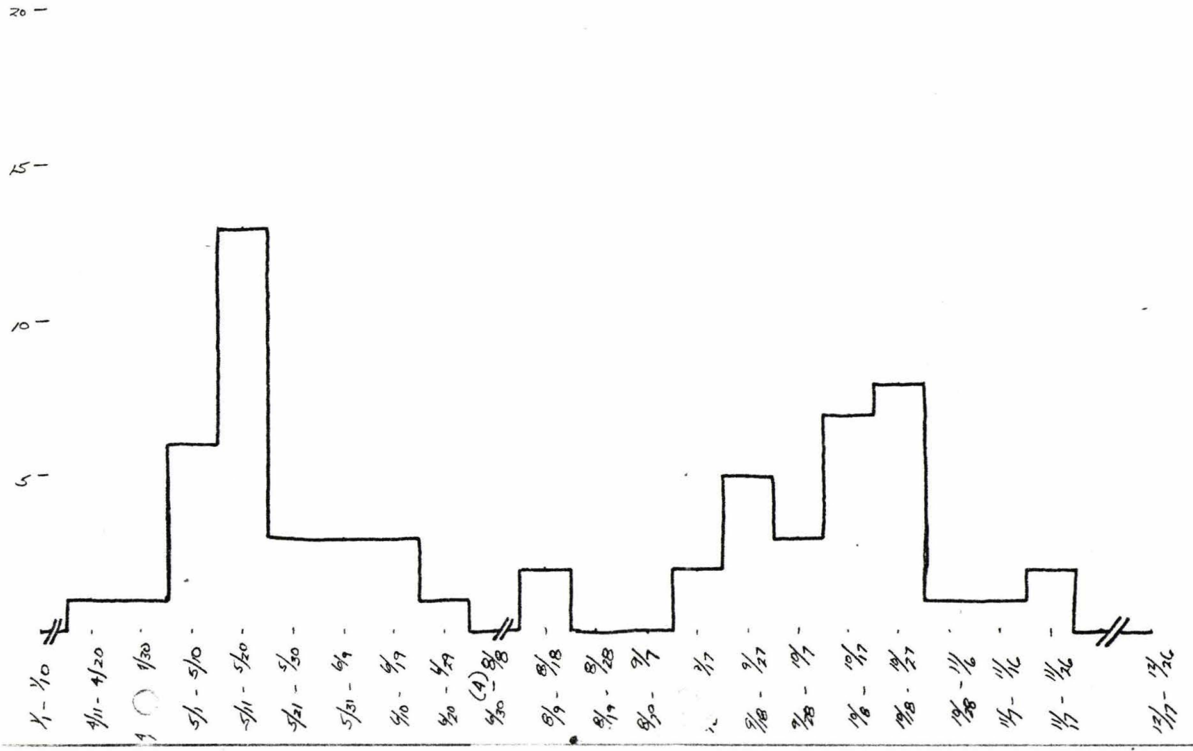
CHEY CROSS C-4

BI 0-30
TEMP 40-65
RH 15-50
WS 5-10
1HR FM 5-30
10 HR FM 5-30



CHEY CROSS C-7

BI 0-30
TEMP 40-65
RH 15-40
WS 5-10
*1 HR FM 5-15
10 HR FM 5-30



CHEY CROSS C-6

BI 0-30
TEMP 40-65
RH 15-40
WS 5-10
*1 HR FM 10-25
10 HR FM 5-30

NO DAYS

CHEY CROSS C-9

BI 0-30
TEMP 40-65
RH 15-40
WS 5-10
1 HR FM 5-15
* 10 HR FM 10-15

NO DAYS

CHEY CROSS C-8

BI 0-30
TEMP 40-65
RH 15-40
WS 5-10
1 HR FM 5-15
*10 HR FM 10-25

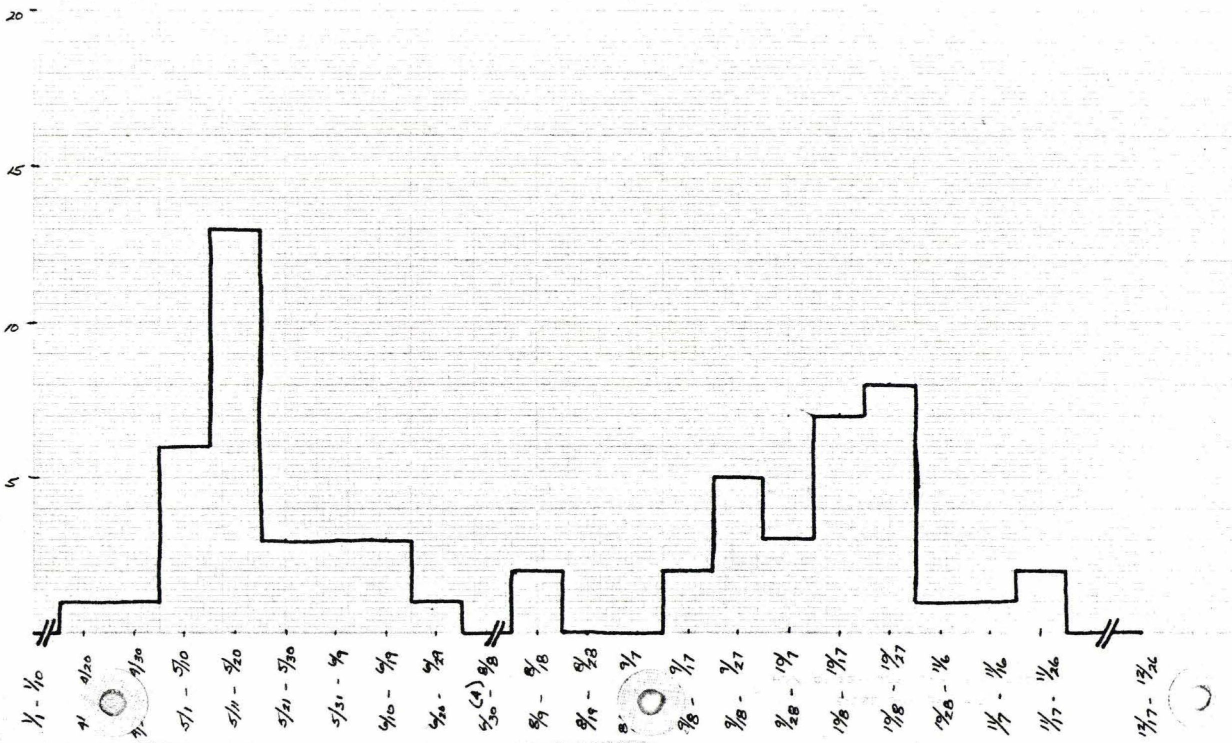
NO DAYS

20
15
10
5

CHEY CROSS C-11

compare to # 9

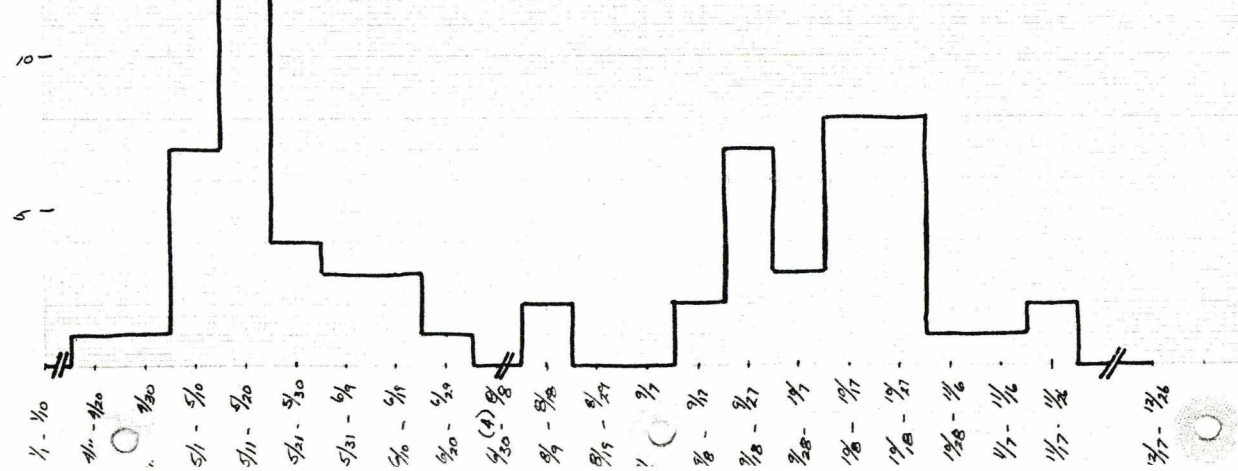
BI 0-30
TEMP 40-65
RH 15-40
WS 5-10
1HR FM 5-15
* 10HR FM 5-15



CHEY CROSS C-10

compare to #7

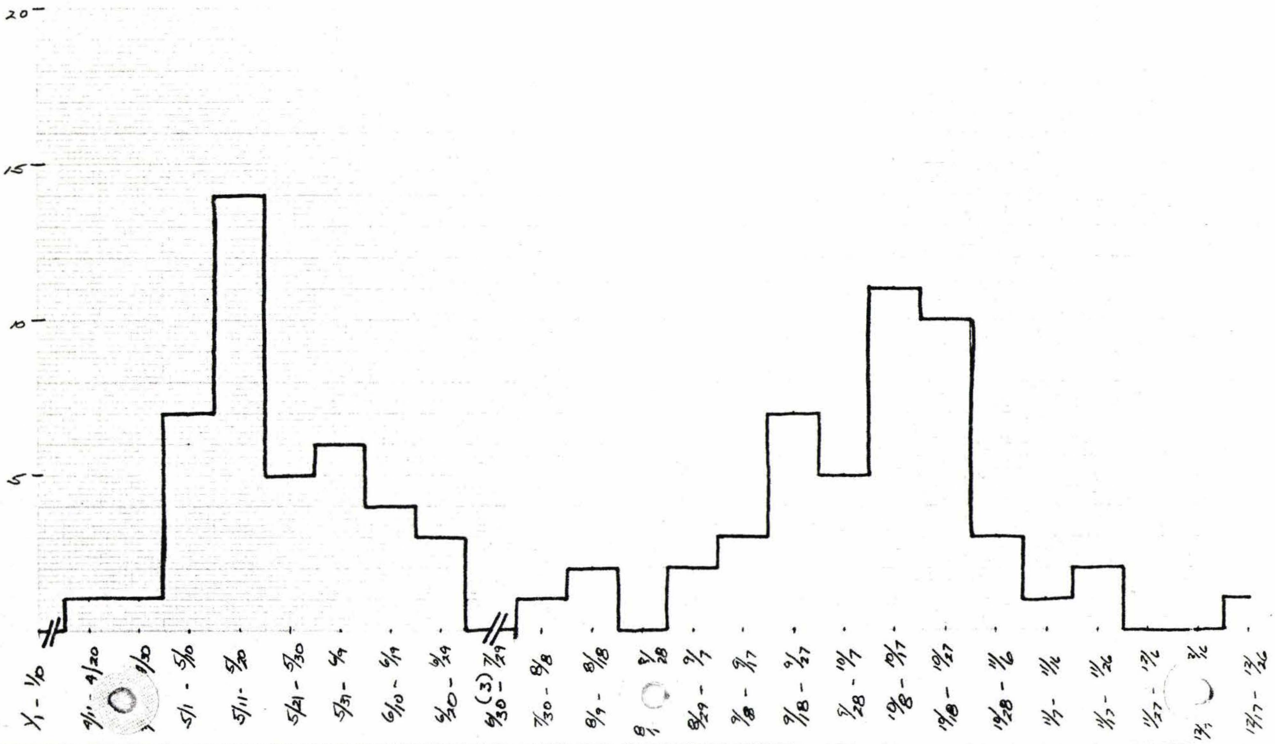
BI 0-30
TEMP 40-65
RH 15-40
* WS 5-15
1HR FM 5-15
10HR FM 5-30



CHEY CROSS C-13

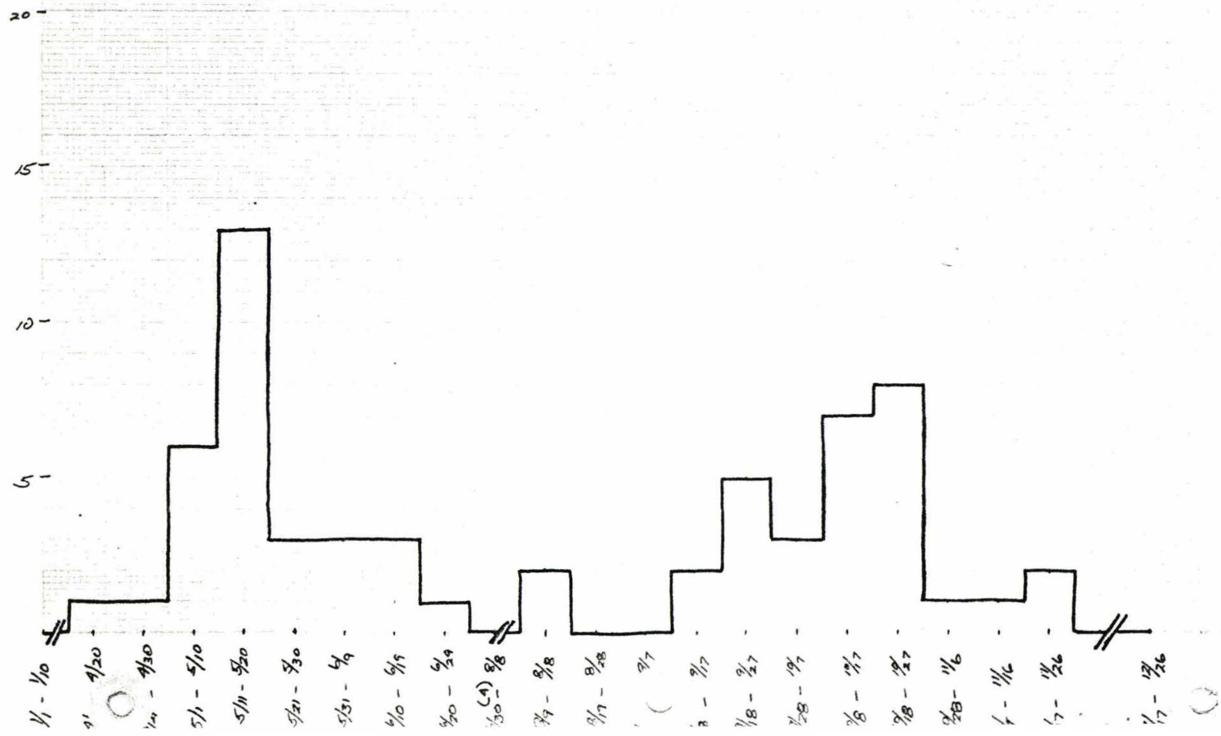
Compare to
#4

BI 0-30
TEMP 40-65
RH 15-50
WS 5-10
1 HR FM 5-10
10 HR FM 5-10



CHEY CROSS C-12

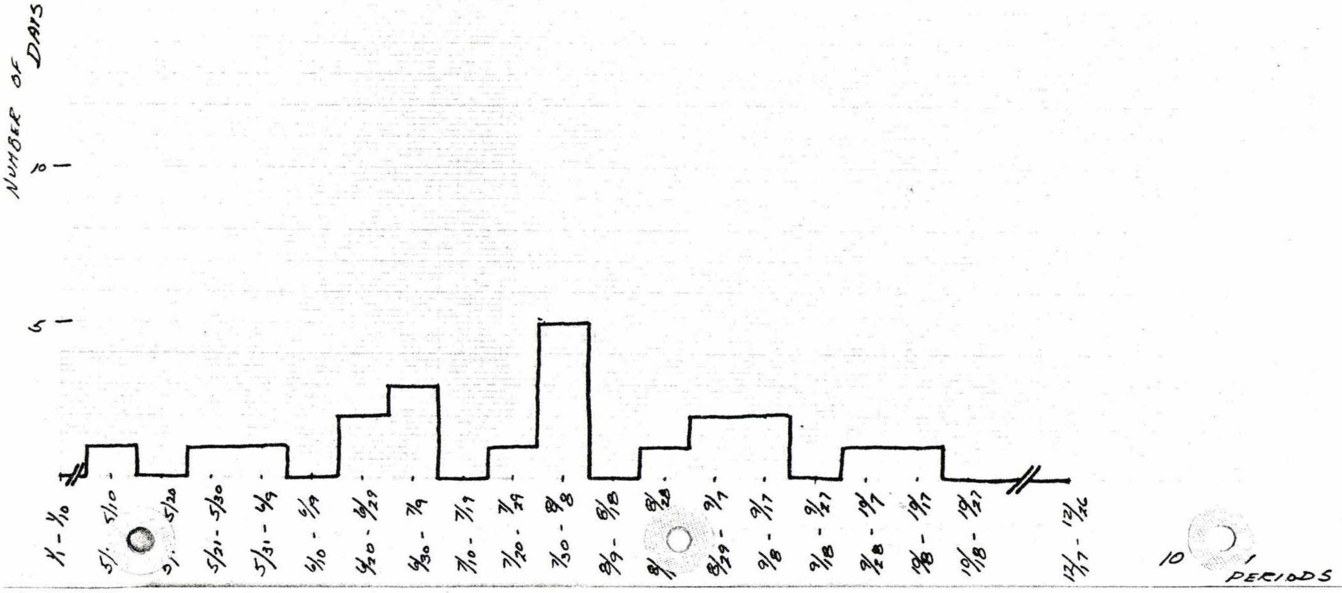
BI 0-30
TEMP 40-65
*RH 10-40
WS 5-10
1 HR FM 5-15
10 HR FM 5-15



NEMO C - 2

BI 0-30
TEMP 65-85
RH 15-50
WS 5-10
*1 HR FM 5-30
10 HR FM 10-30

TOTAL NUMBER OF DAYS MEETING PRESCRIPTION, BY 10 DAY PERIODS, FOR 10 YEARS



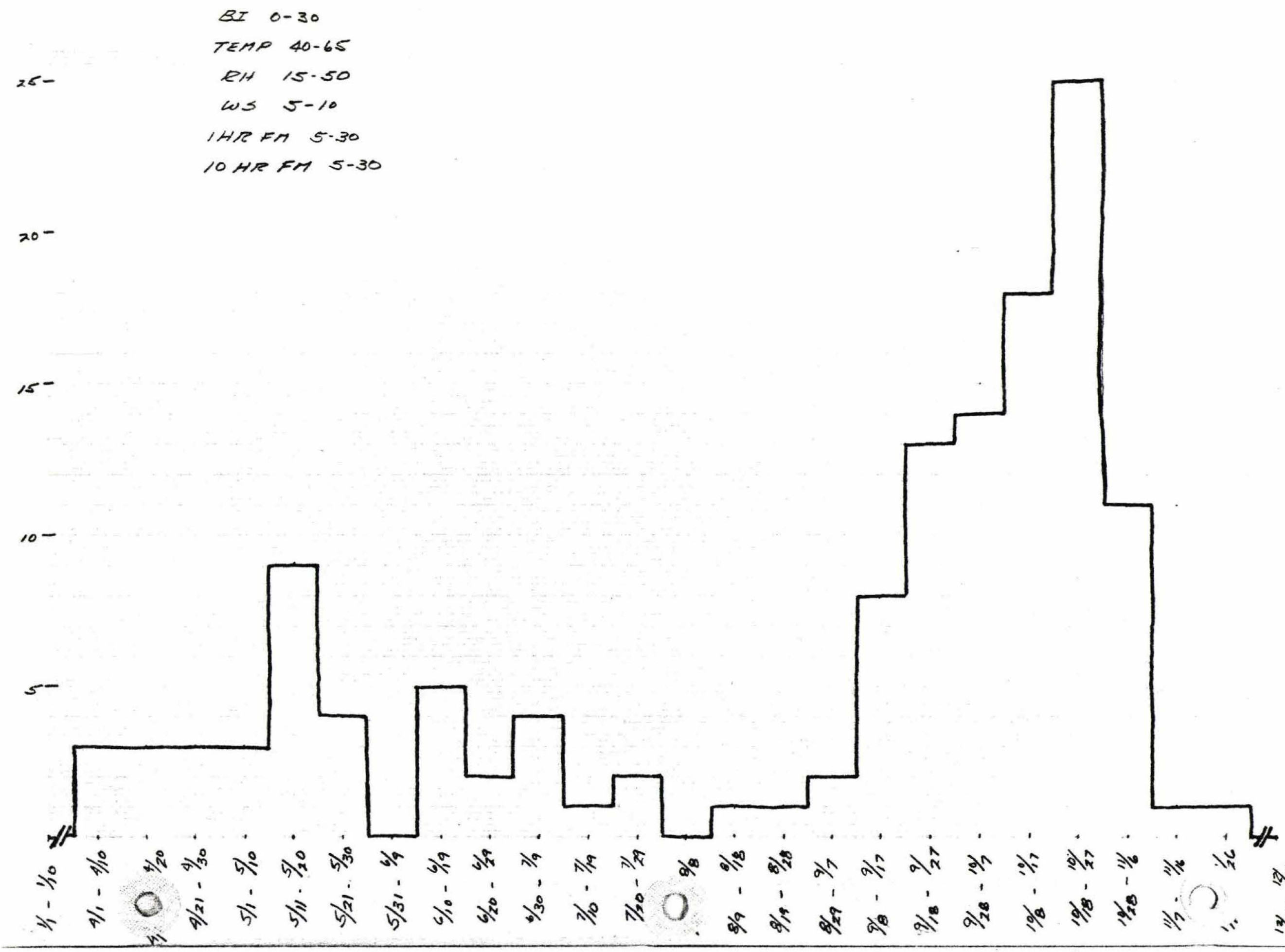
NEMO C-1

BI 0-30
TEMP 65-85
RH 15-50
WS 5-10
1 HR FM 10-25
10 HR FM 10-30

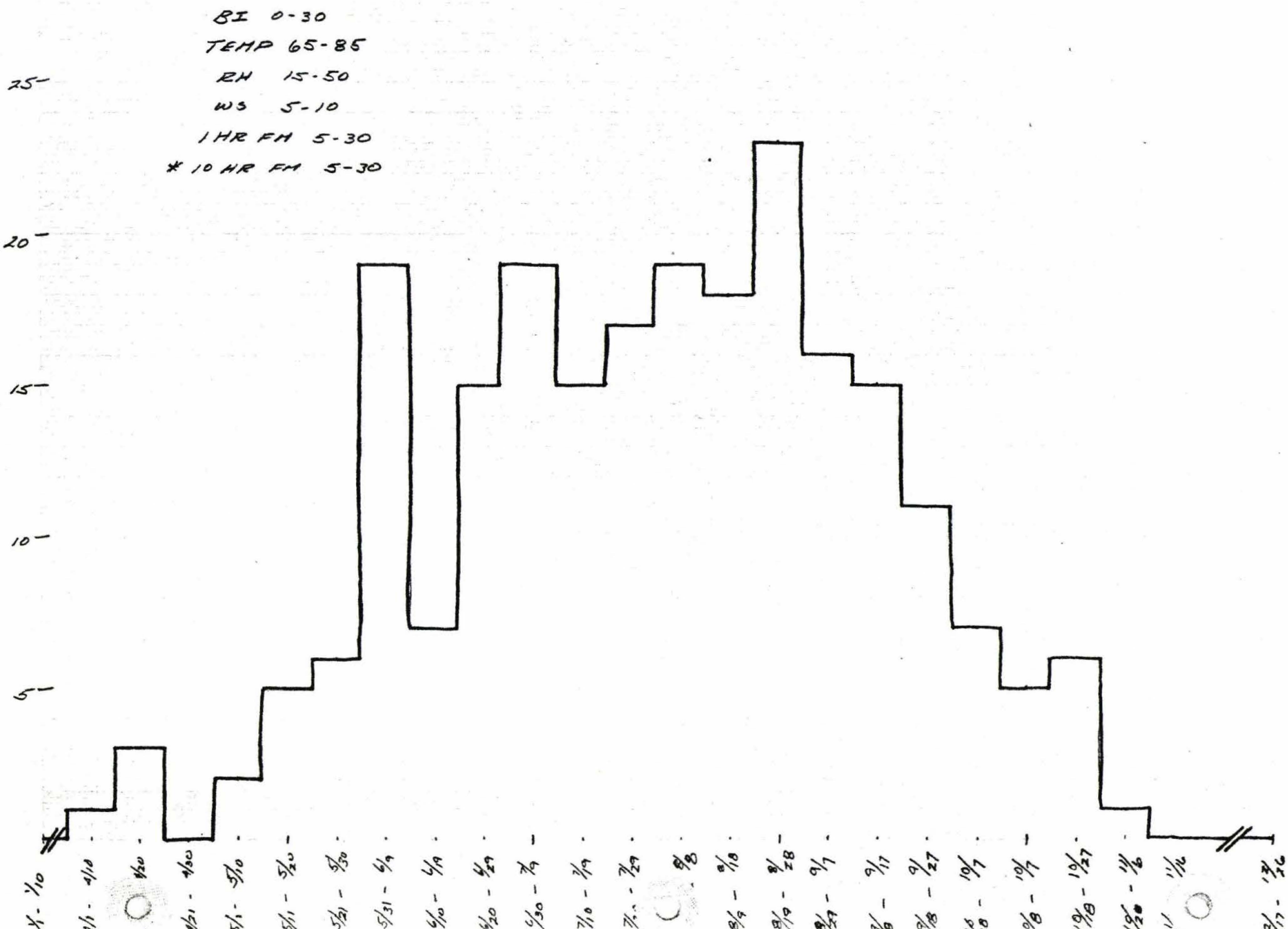
1 DAY

7/30 - 8/8

NEMO C-4


BI 0-30
TEMP 40-65
RH 15-50
WS 5-10
1 HR FM 5-30
10 HR FM 5-30

NEMO C-3


BI 0-30
TEMP 65-85
RH 15-50
WS 5-10
1 HR FM 5-30
* 10 HR FM 5-30

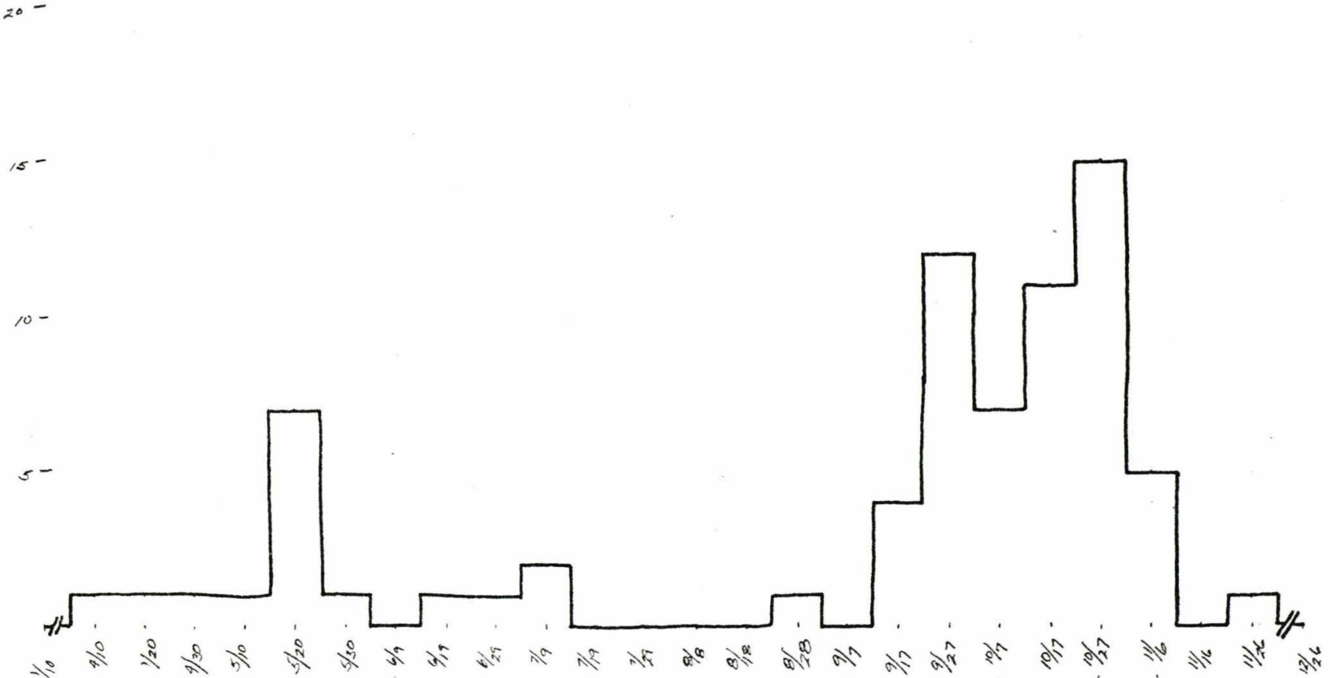
NEMO C-6

BI 0-30
TEMP 40-65
RH 15-40
WS 5-10
*1HR FM 10-25
10HR FM 5-30

No DAYS

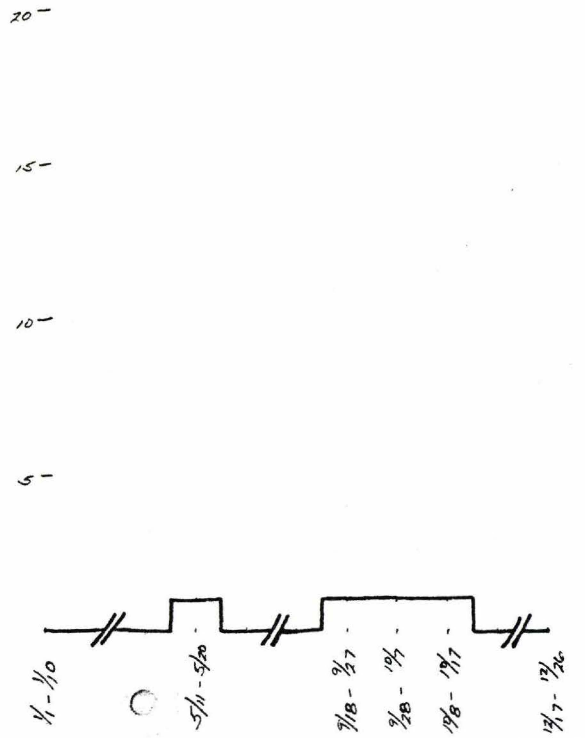
NEMO C-5

BI 0-30
TEMP 40-65
RH 15-40
WS 5-10
1HR FM 5-30
10 HR FM 5-30



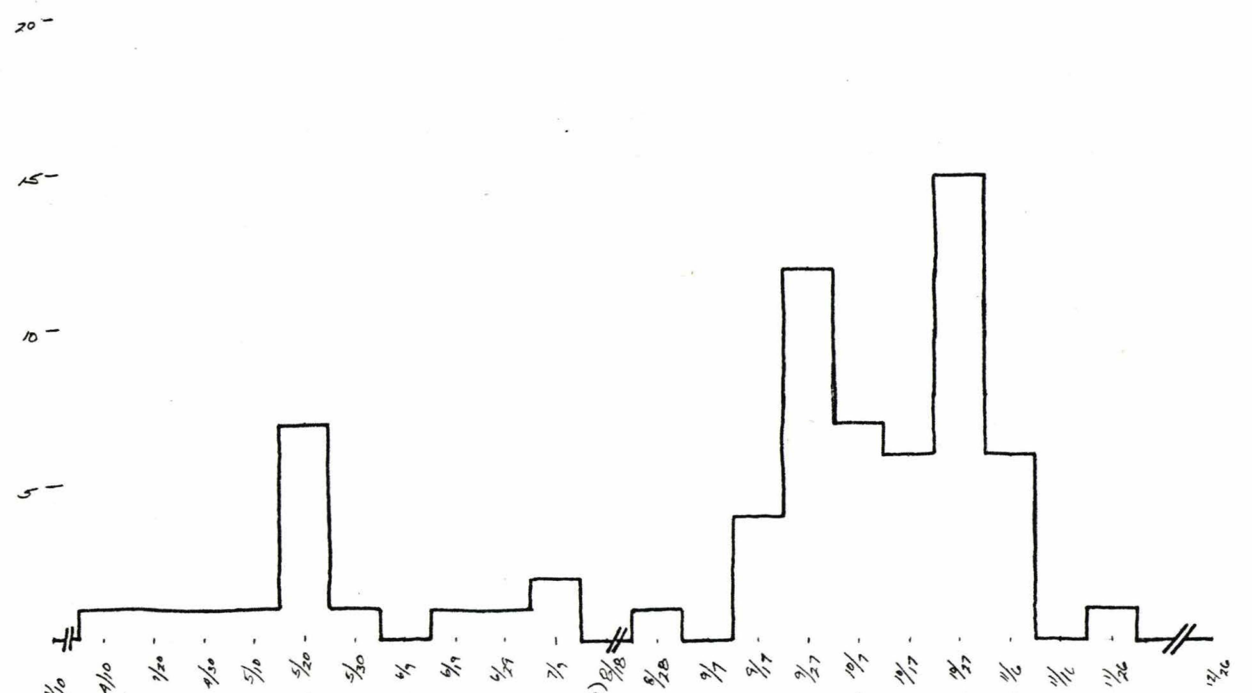
NEMO C-8

BI 0-30
TEMP 40-65
RH 15-40
WS 5-10
1HR FM 5-15
*10 HR M 10-25



NEMO C-7

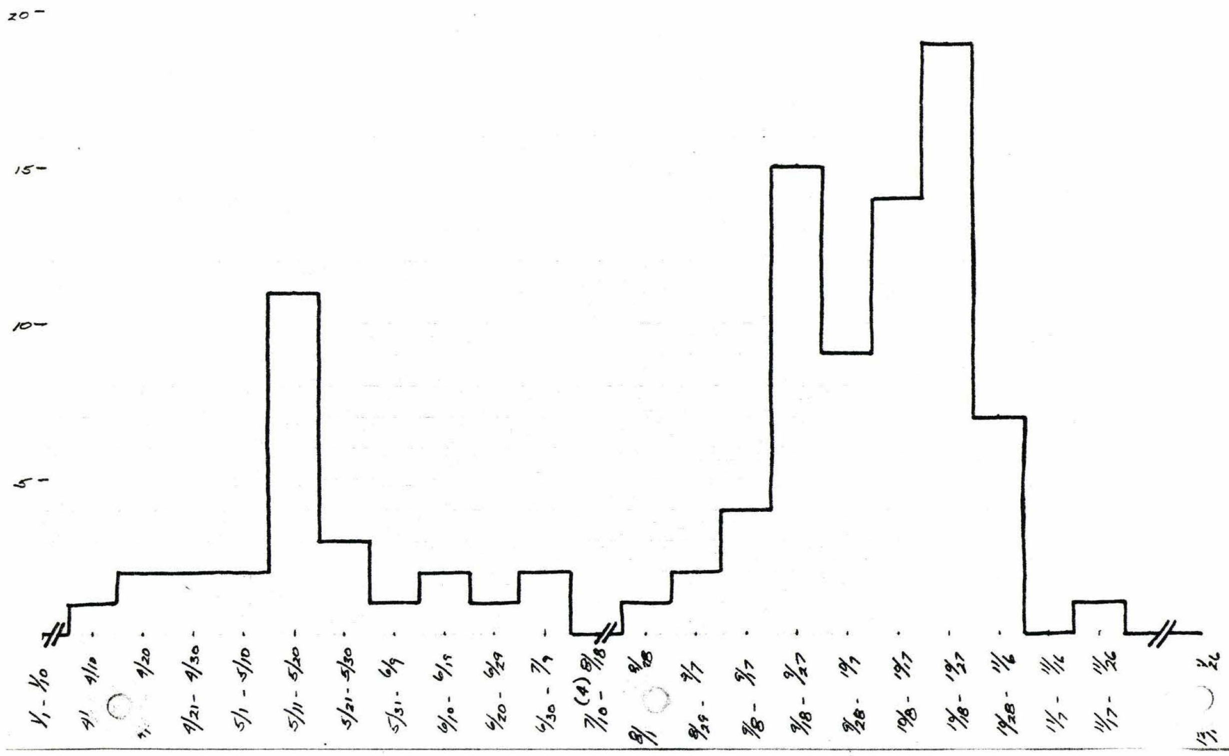
BI 0-30
TEMP 40-65
RH 15-40
WS 5-10
*1HR FM 5-15
10 HR FM 5-30



NEMO C-10

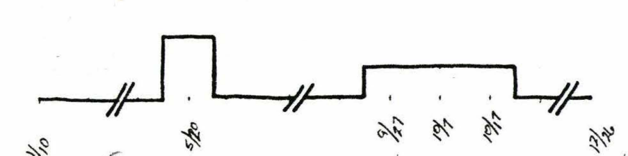
compare to
#7

BI 0-30
TEMP 40-65
RH 15-40
* WS 5-15
1 HR FM 5-15
10 HR FM 5-30



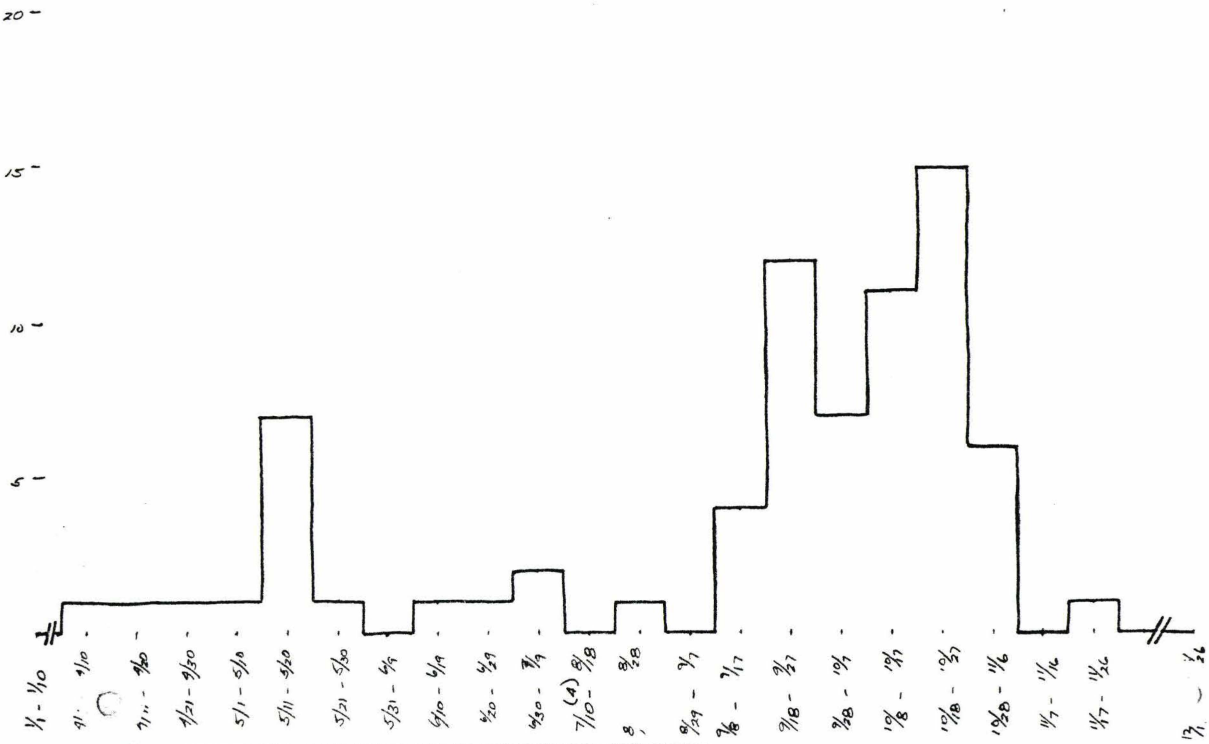
NEMO C-9

BI 0-30
TEMP 40-65
RH 15-40
WS 5-10
1 HR FM 5-15
* 10 HR FM 10-15



NEMO C-12

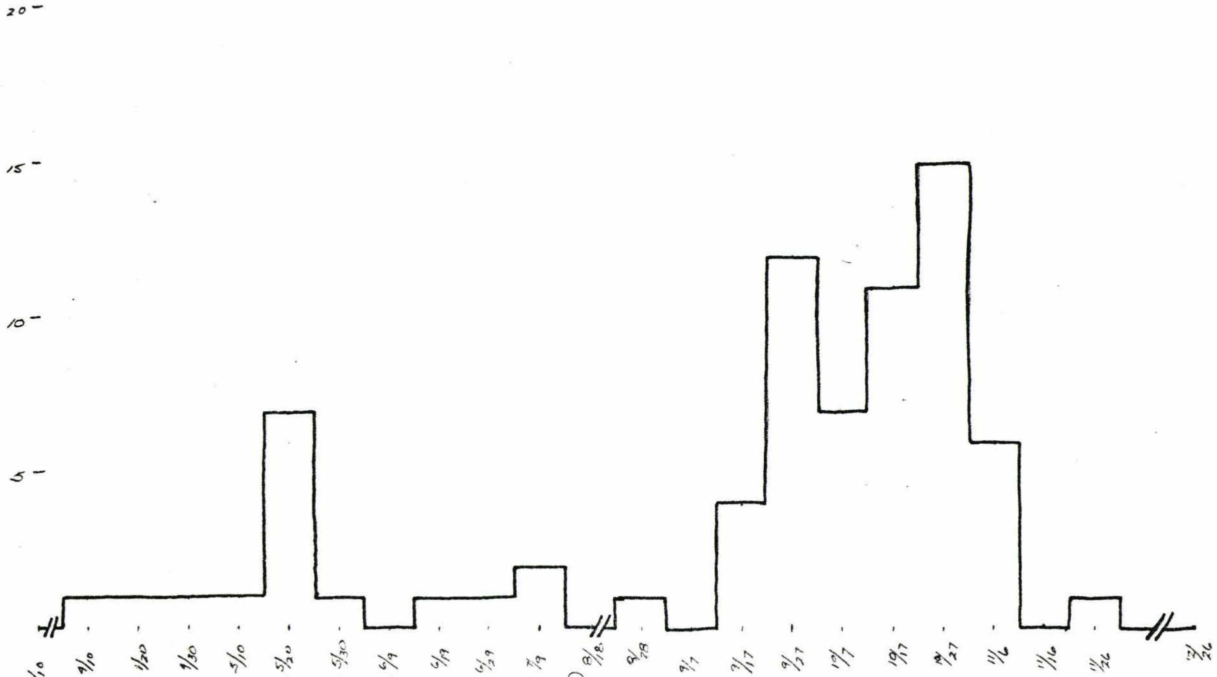
BI 0-30
TEMP 40-65
* RH 10-40
WS 5-10
1HR FM 5-15
10HR FM 5-15



NEMO C-11

compare to
# 9

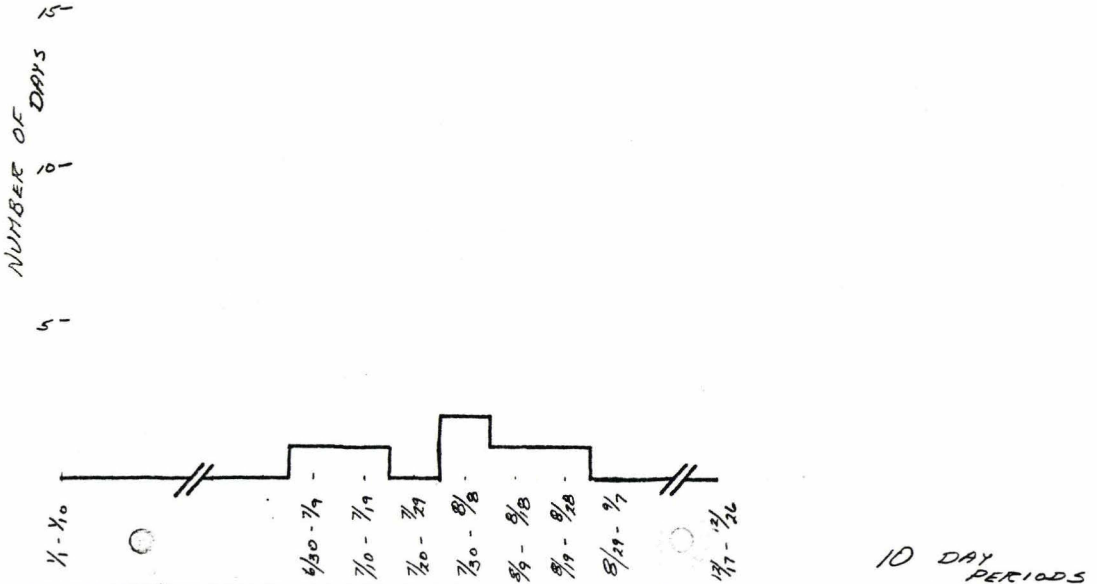
BI 0-30
TEMP 40-65
RH 15-40
WS 5-10
1HR FM 5-15
* 10HR FM 5-15



CUSTER C-1

BI 0-30
TEMP 65-85
RH 15-50
WS 5-10
1 HR FM 10-25
10 HR FM 10-30

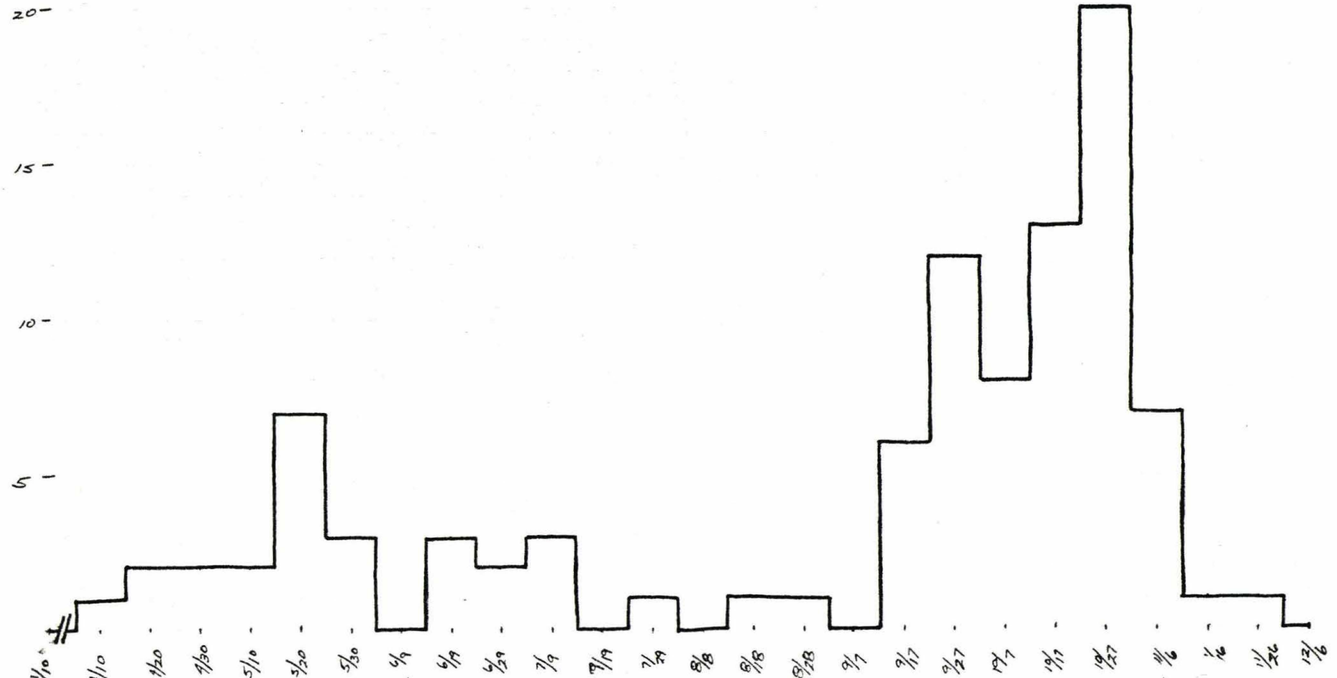
TOTAL NUMBER OF DAYS MEETING PRESCRIPTION, FOR EACH 10 DAY PERIOD FOR 10 YEARS.



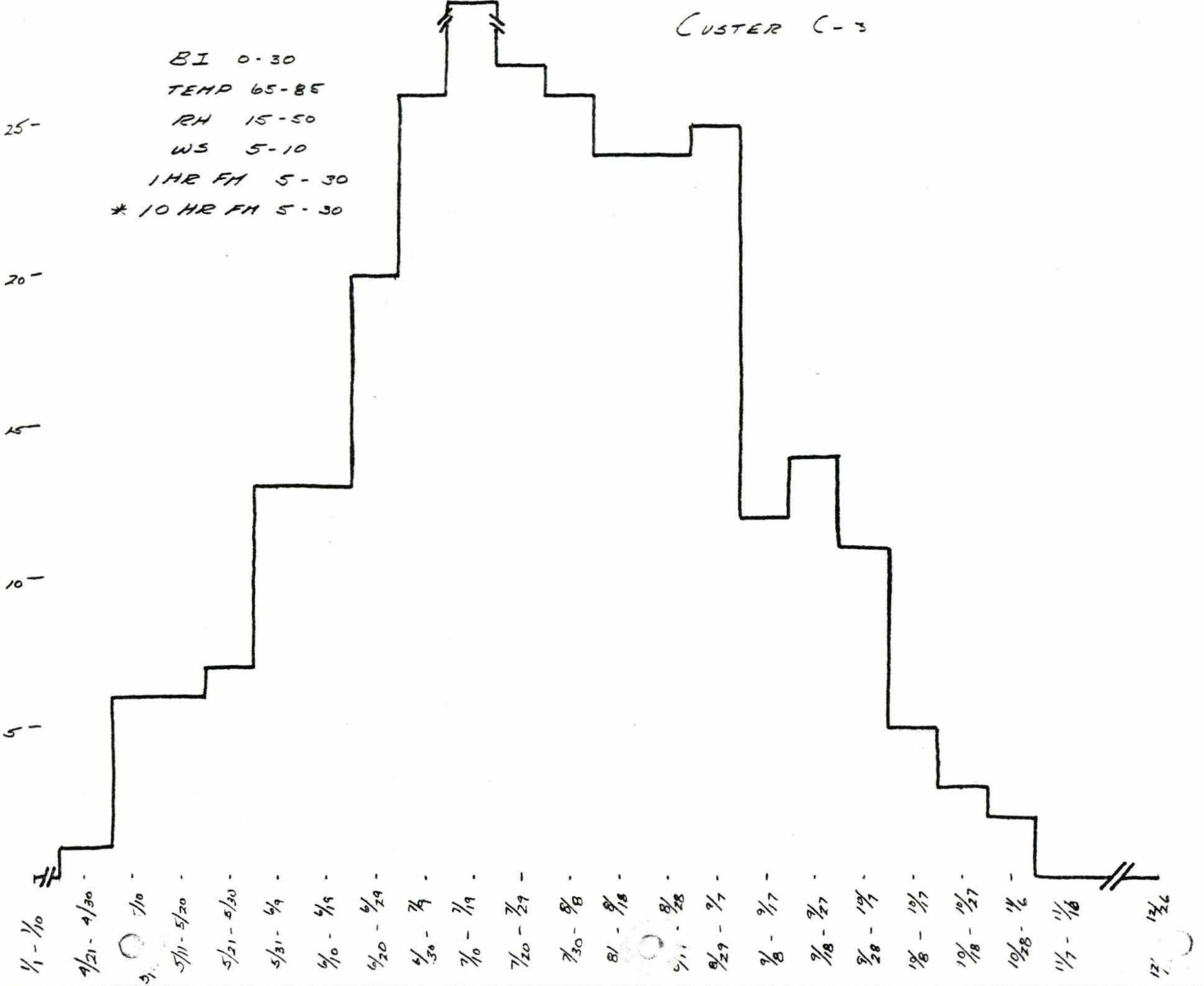
NEMO C-13

compare to #4

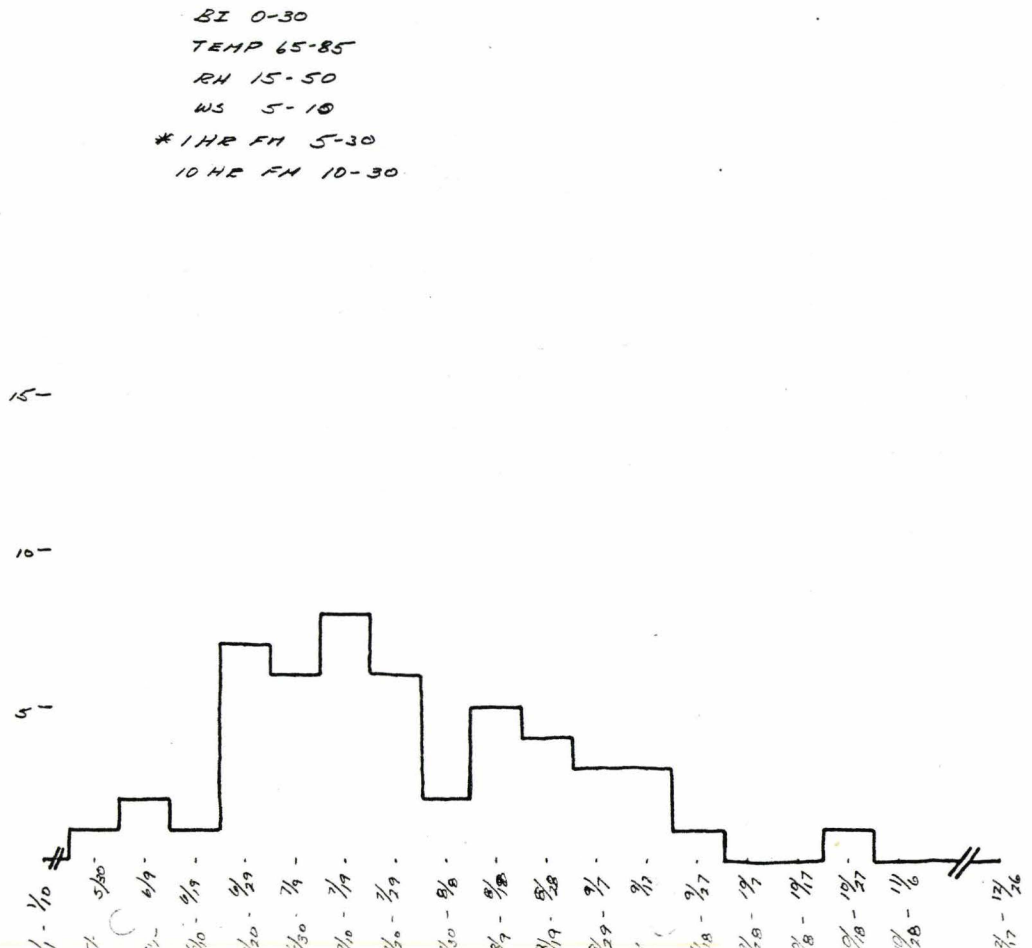
BI 0-30
TEMP 40-65
RH 15-50
WS 5-10
1HR FM 5-10
10 HR FM 5-10



CUSTER C-3

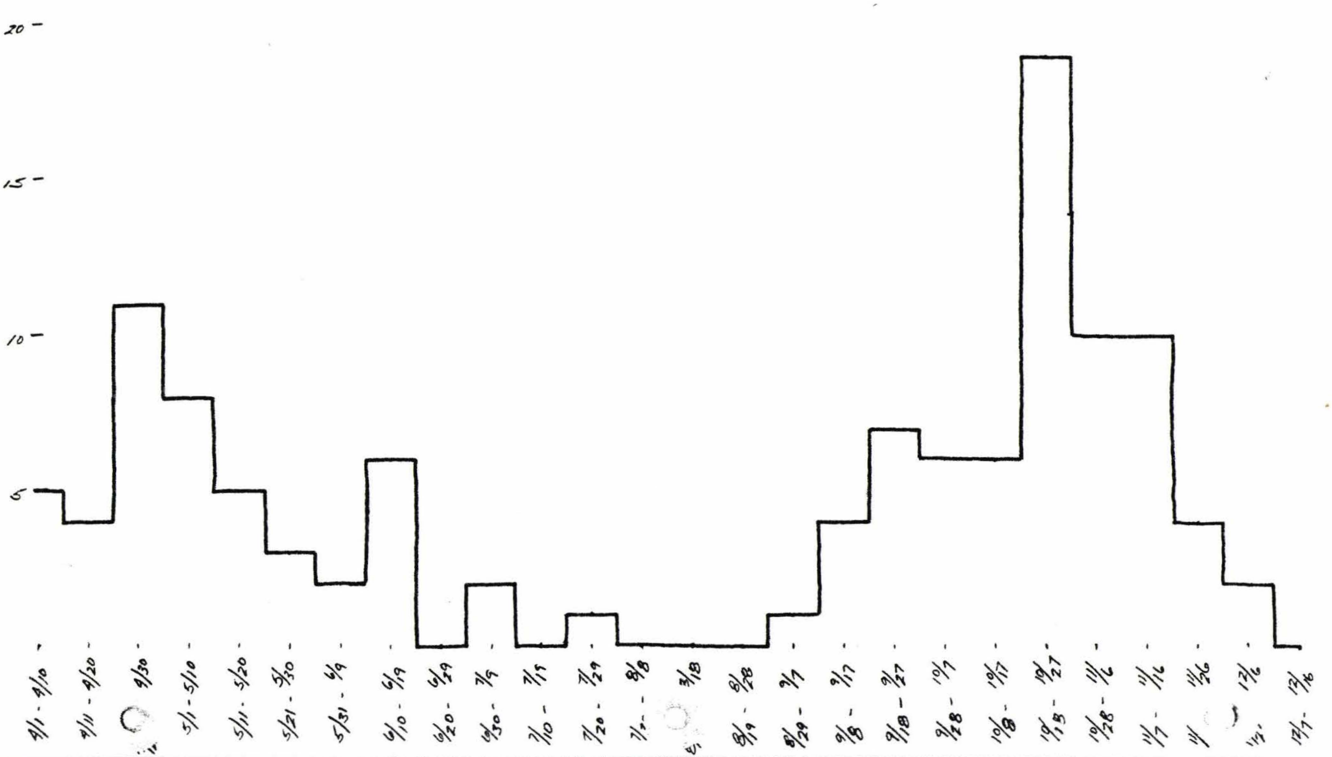

BI 0-30
TEMP 65-85
RH 15-50
WS 5-10
1 HR FM 5-30
* 10 HR FM 5-30

CUSTER C-2


BI 0-30
TEMP 65-85
RH 15-50
WS 5-10
* 1 HR FM 5-30
10 HR FM 10-30

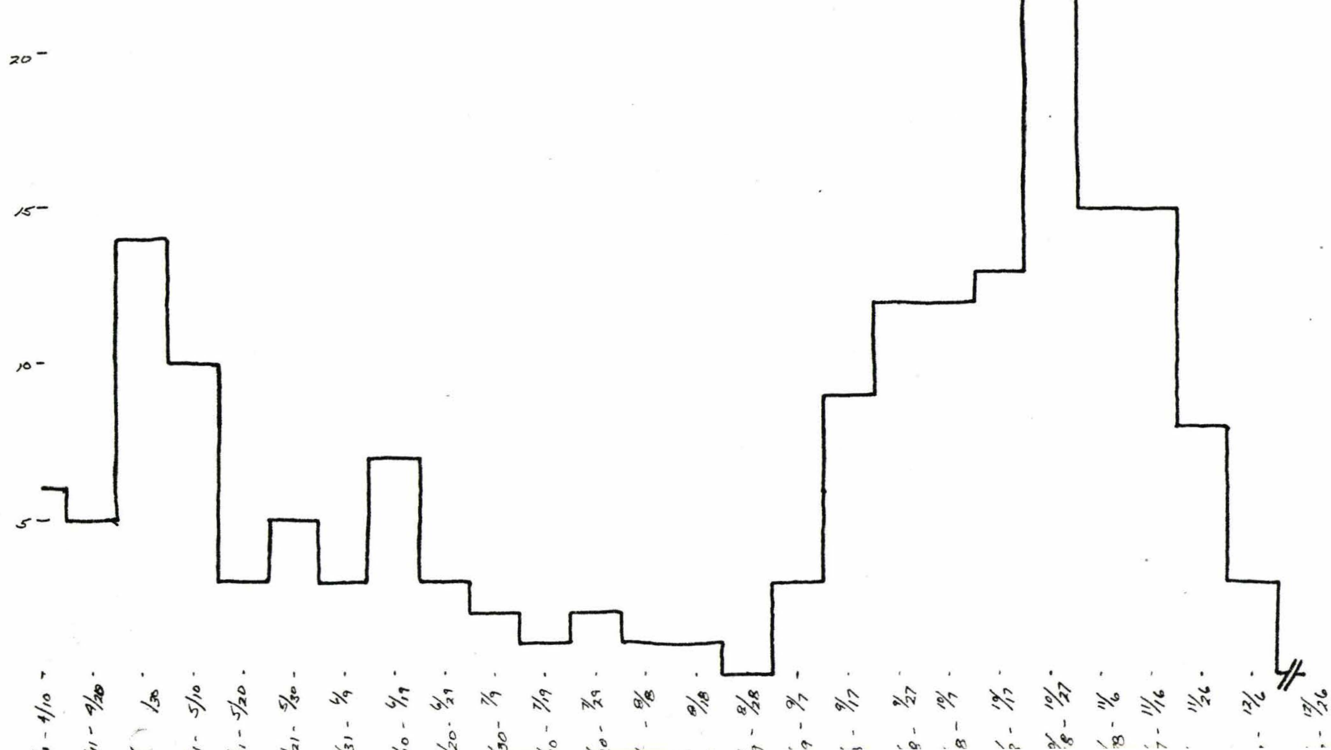
CUSTER C-5

BI 0-30
TEMP 40-65
RH 15-40
WS 5-10
1 HR FM 5-30
10 HR FM 5-30



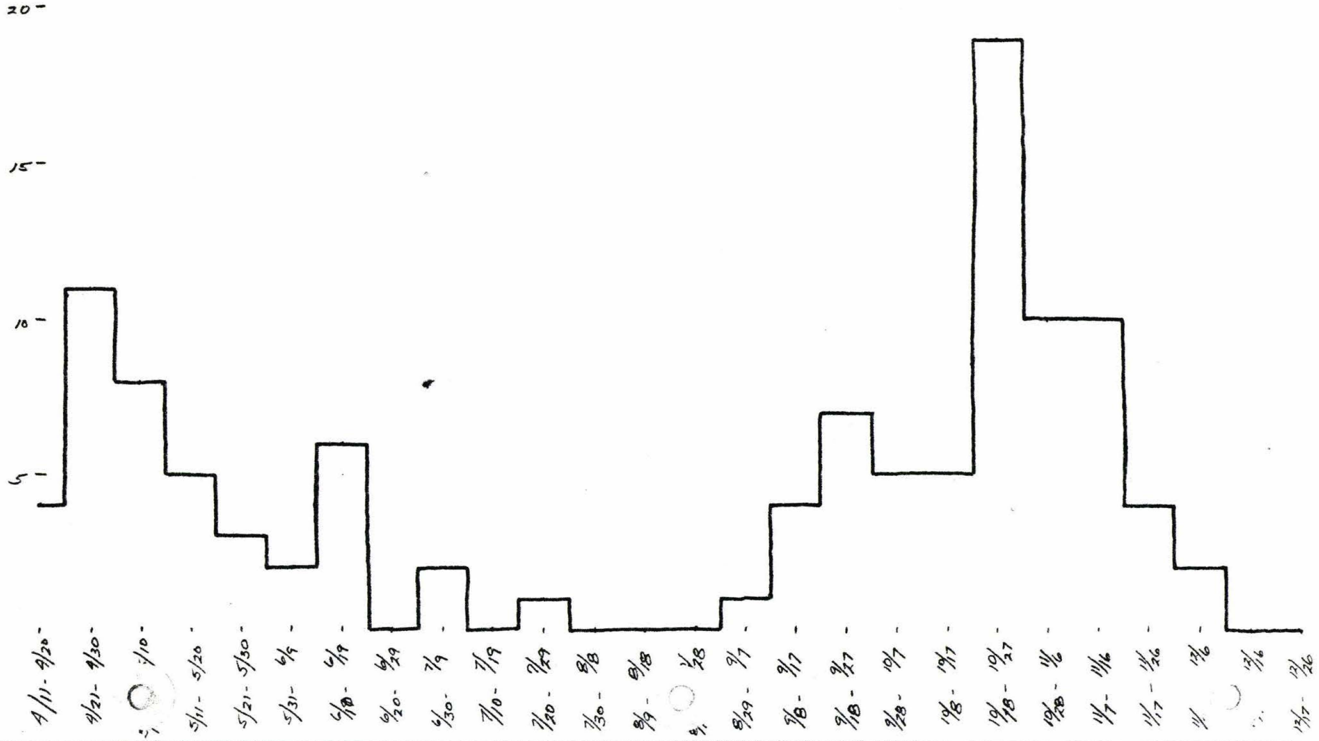
CUSTER C-4

BI 0-30
* TEMP 40-65
RH 15-50
WS 5-10
1 HR FM 5-30
10 HR FM 5-30



CUSTER C-7

BI 0-30
TEMP 40-65
RH 15-40
WS 5-10
* 1 HR FM 5-15
10 HR FM 5-30



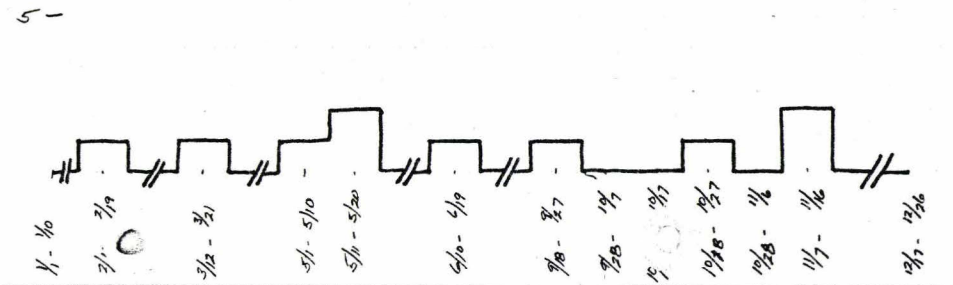
CUSTER C-6

BI 0-30
TEMP 40-65
RH 15-40
WS 5-10
* 1 HR FM 10-25
10 HR FM 5-30

NO DAYS

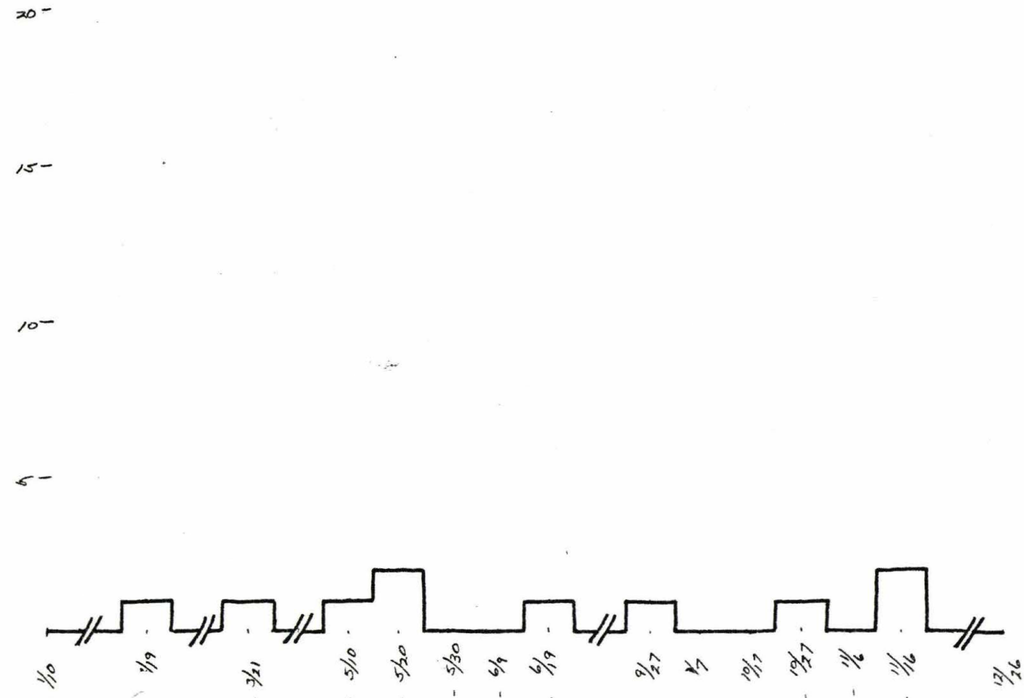
CUSTER C-9

BI 0-30
TEMP 40-65
RH 15-40
WS 5-10
1 HR FM 5-15
*10 HR FM 10-15



CUSTER C-8

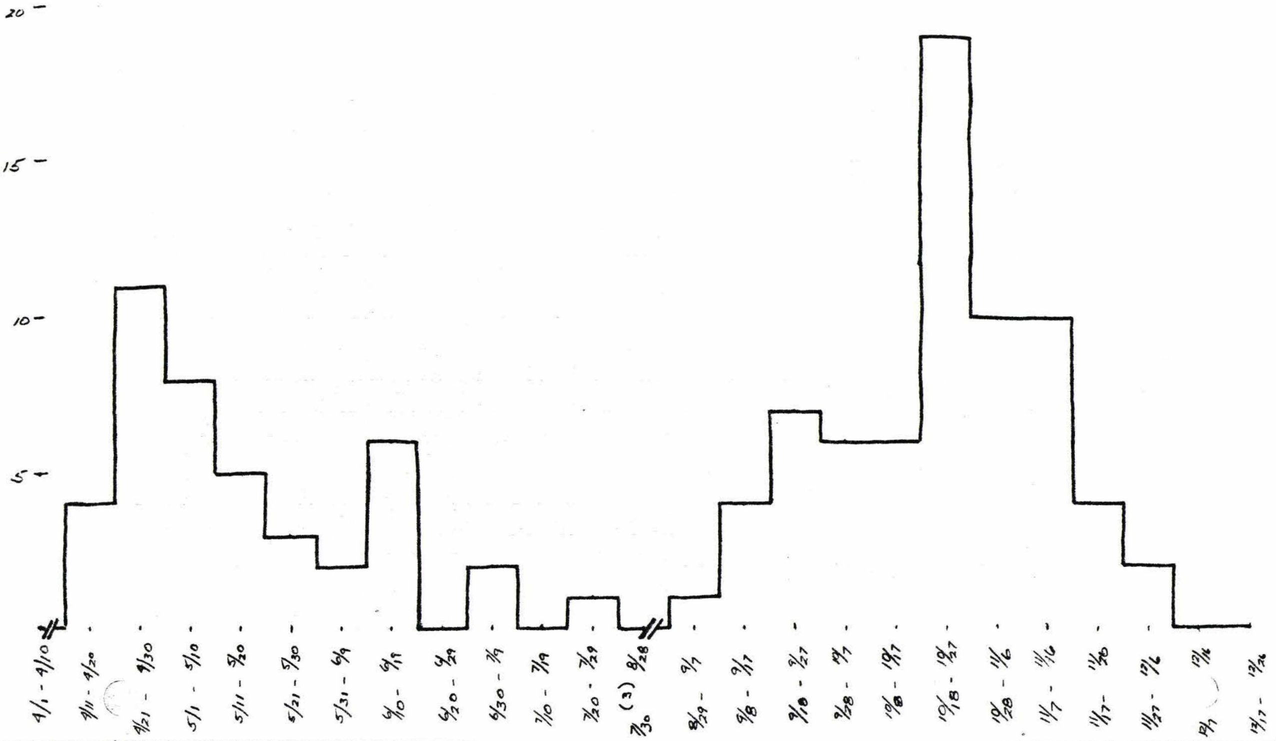
BI 0-30
TEMP 40-65
RH 15-40
WS 5-10
1 HR FM 5-15
* 10 HR FM 10-25



CUSTER C-11

compare to
#9

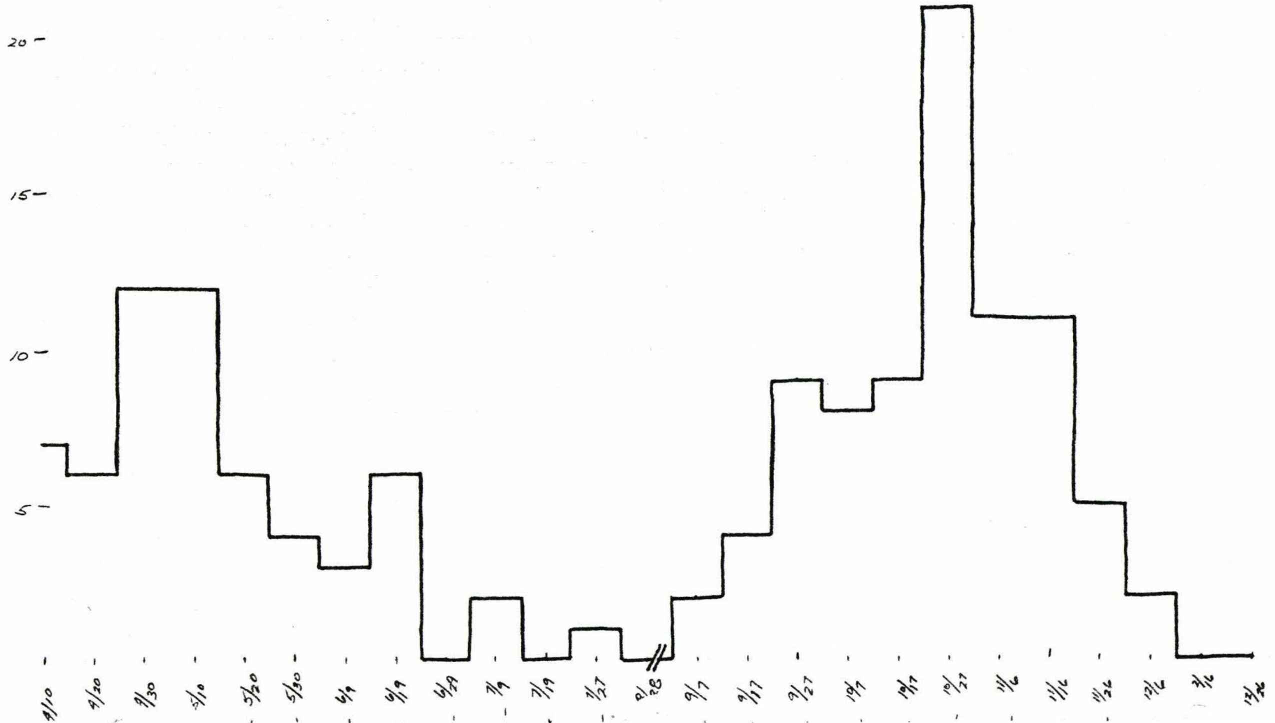
BI 0-30
TEMP 40-65
RH 15-40
WS 5-10
1HR FM 5-15
* 10 HR FM 5-15



CUSTER C-10

compare to
#7

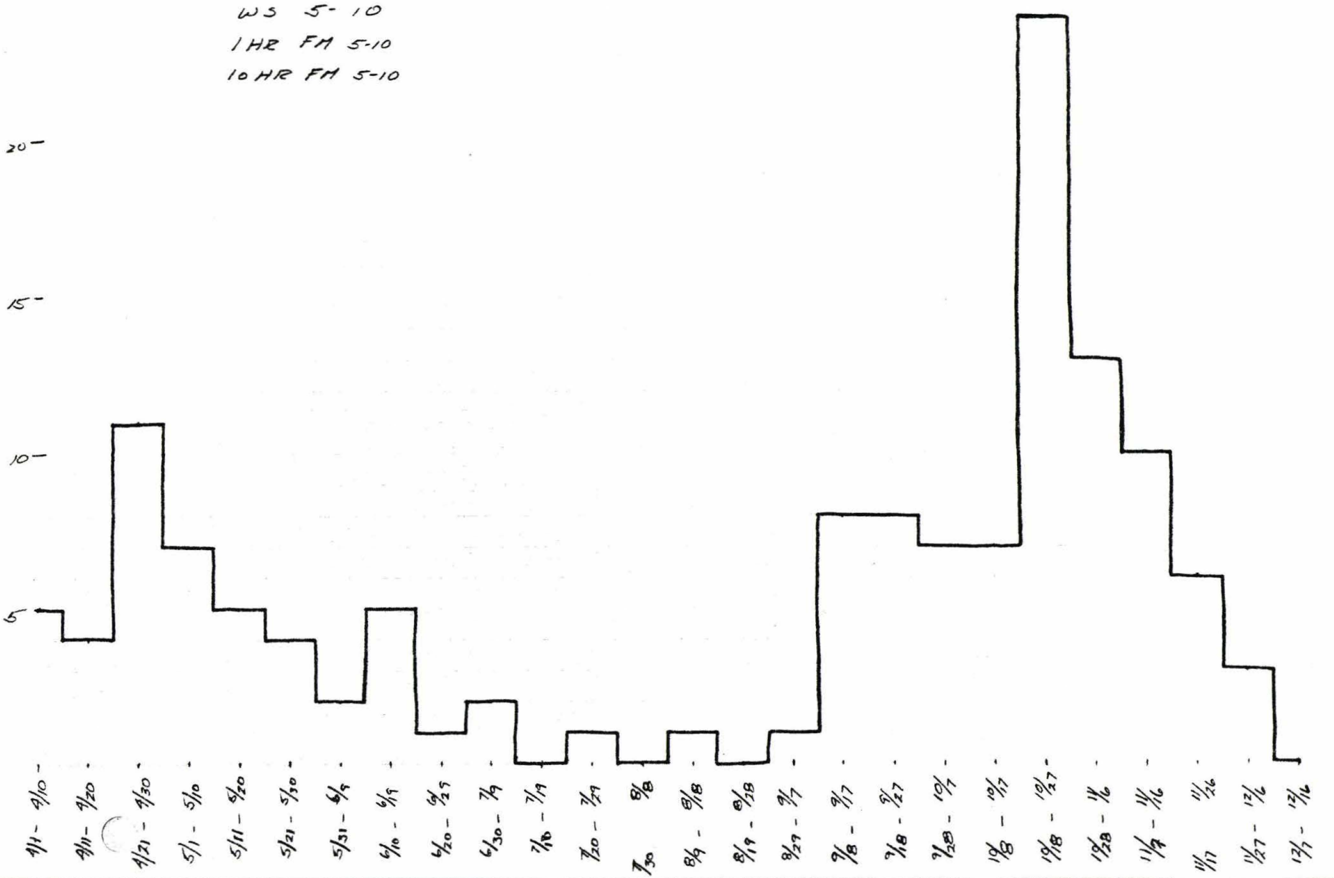
BI 0-30
TEMP 40-65
RH 15-40
* WS 5-15
1HR FM 5-15
10 HR FM 5-30



compare to
#4

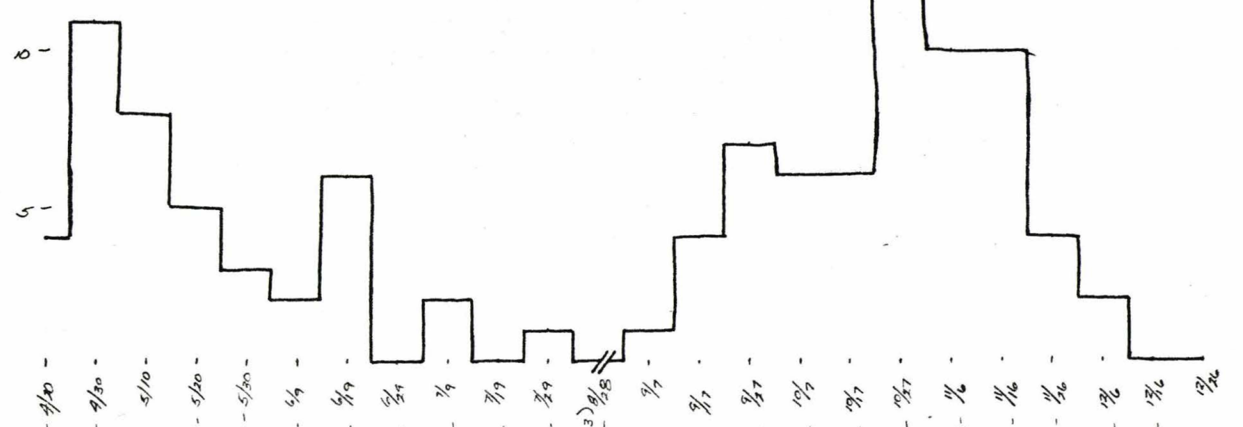
CUSTER C-13

BI 0-30
TEMP 40-65
RH 15-50
WS 5-10
1 HR FM 5-10
10 HR FM 5-10



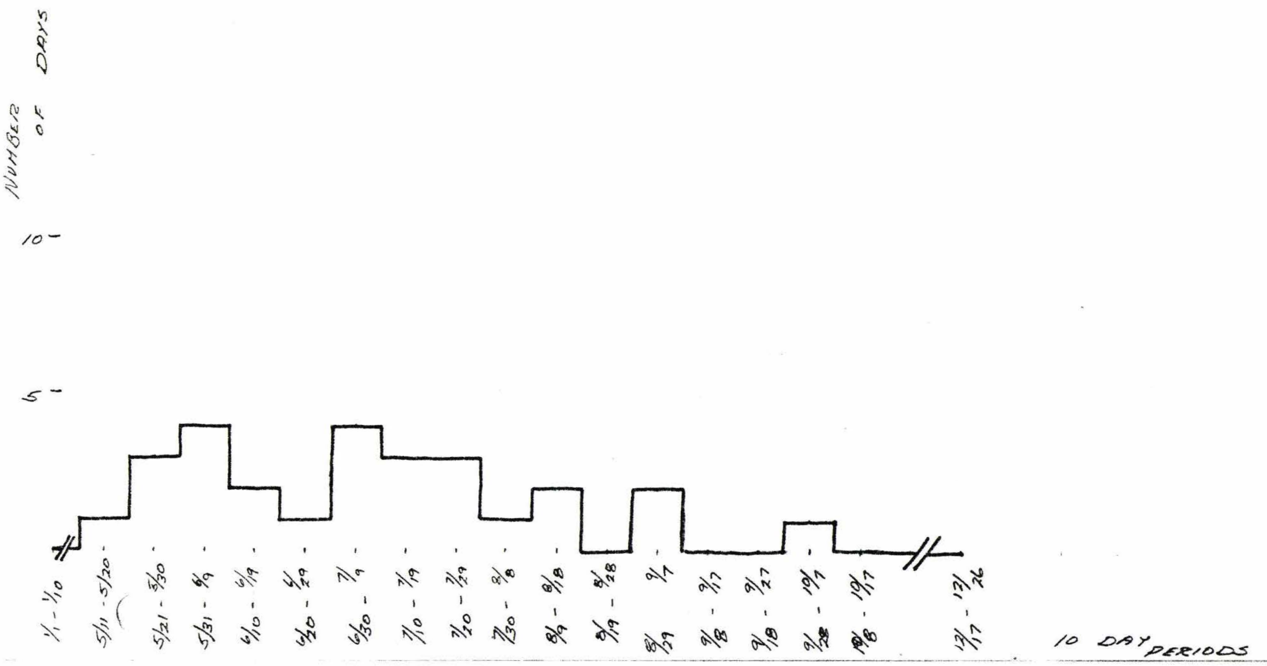
CUSTER C-12

BI 0-30
TEMP 40-65
* RH 10-40
WS 5-10
1 HR FM 5-15
10 HR FM 5-15



TEPEE C-2

BI 0-30
TEMP 65-85
RH 15-50
WS 5-10
* 1 HR FM 5-30
10 HR FM 10-30



TEPEE C-1

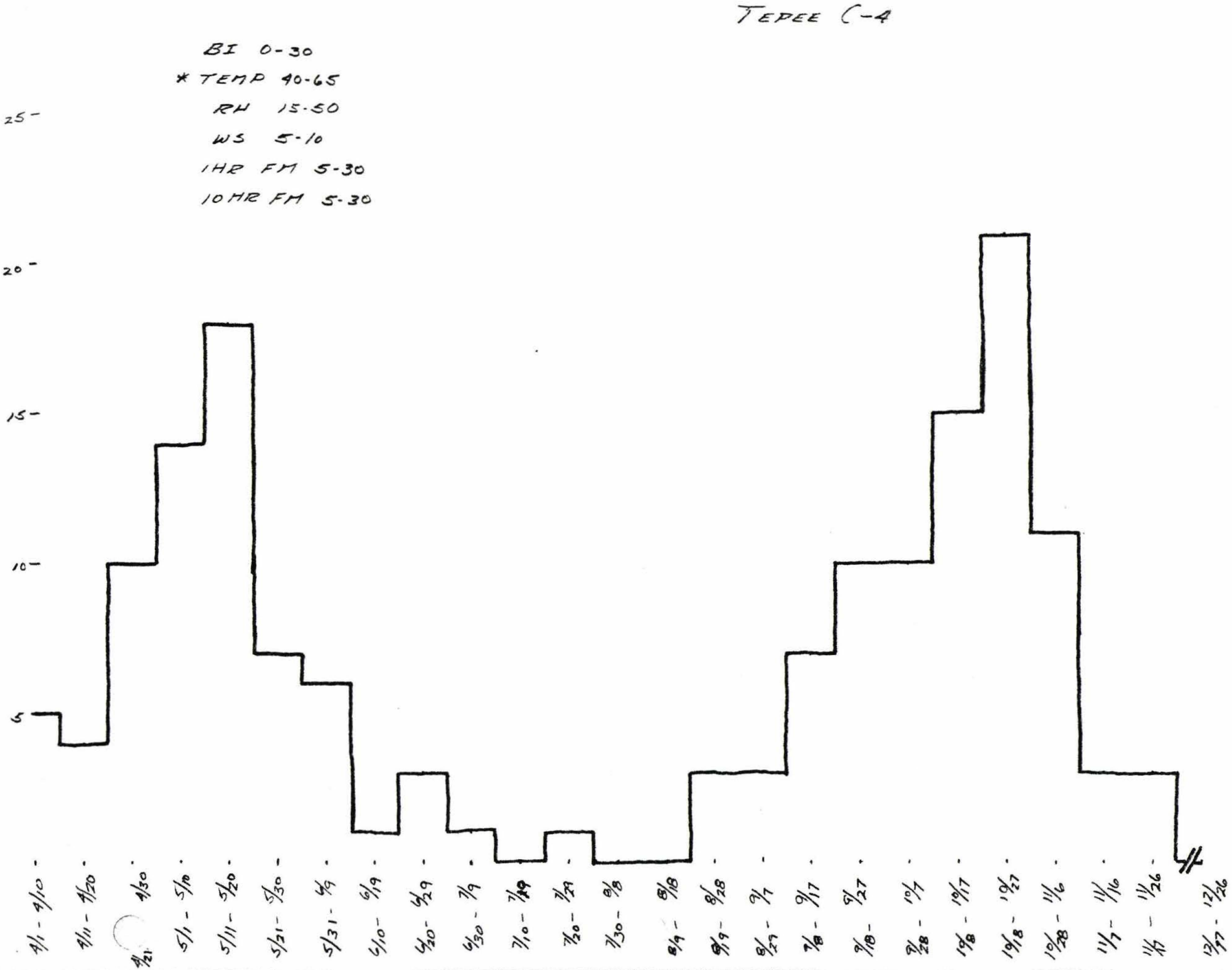
BI 0-35
TEMP 65-85
RH 15-50
WS 5-10
1 HR FM 10-25
10 HR FM 10-30

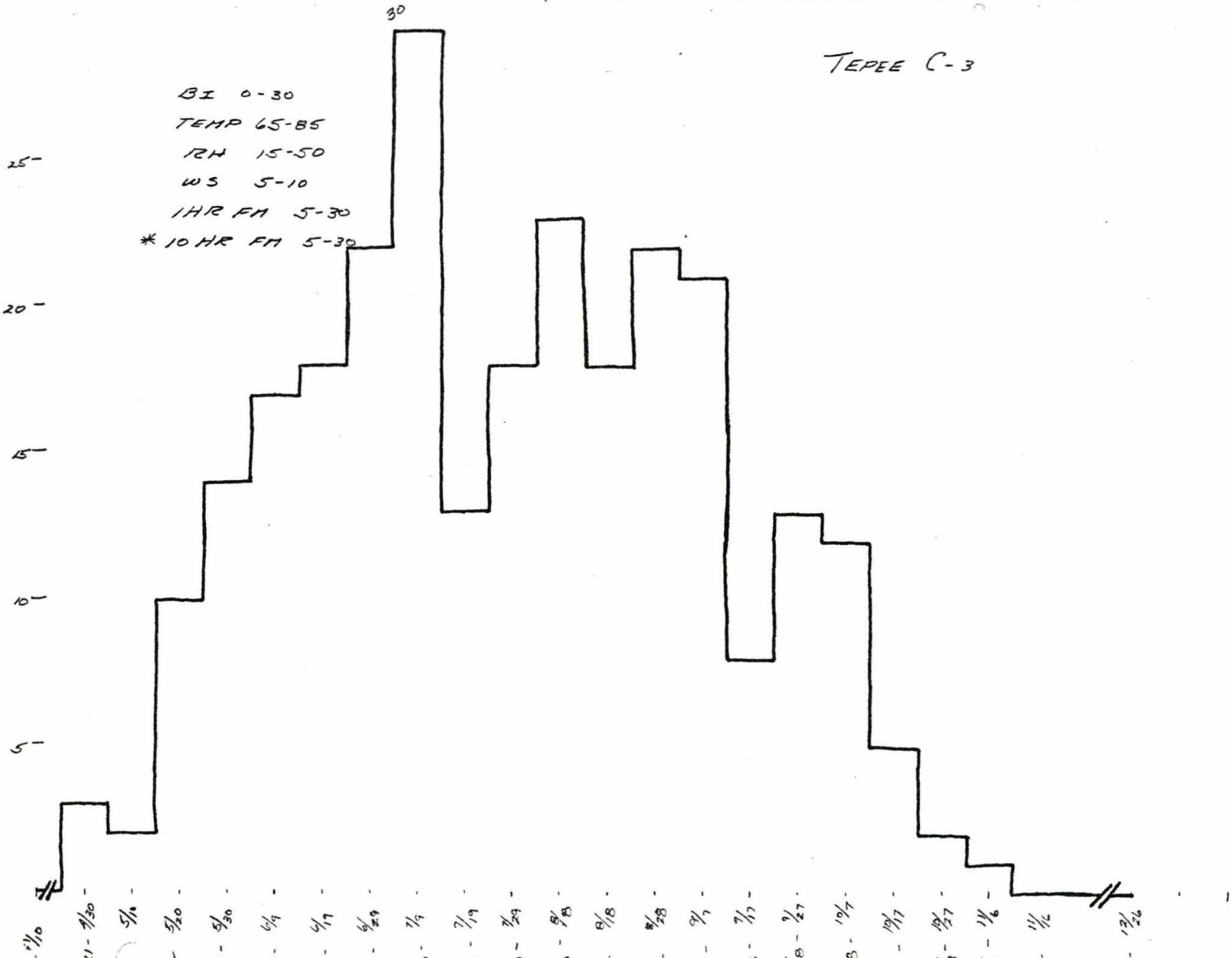
TOTAL NUMBER OF DAYS MEETING PRESCRIPTION, EACH 10 DAY PERIOD FOR 10 YEARS.

1 DAY

5/21- 5/30

NUMBER OF DAYS


TEPEE C-4


TEPEE C-3

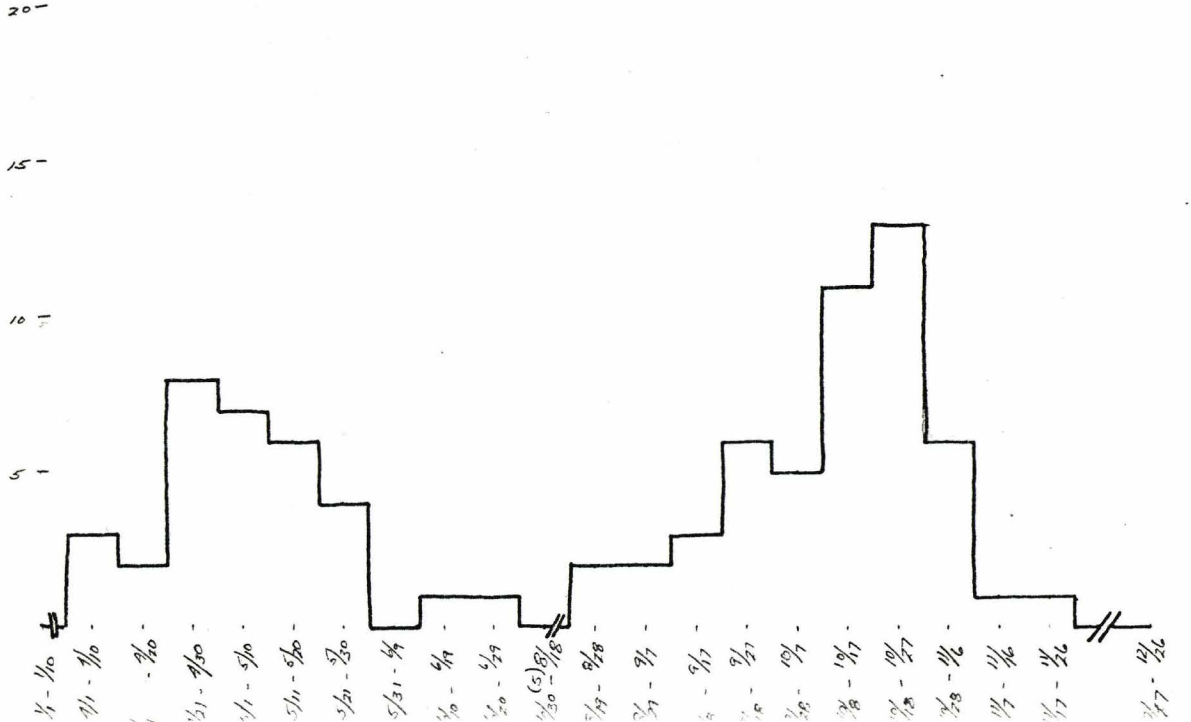
TEPEE C-6

BI 0-30
TEMP 40-65
RH 15-40
WS 5-10
* 1HR FM 10-25
10 HR FM 5-30

NO DAYS

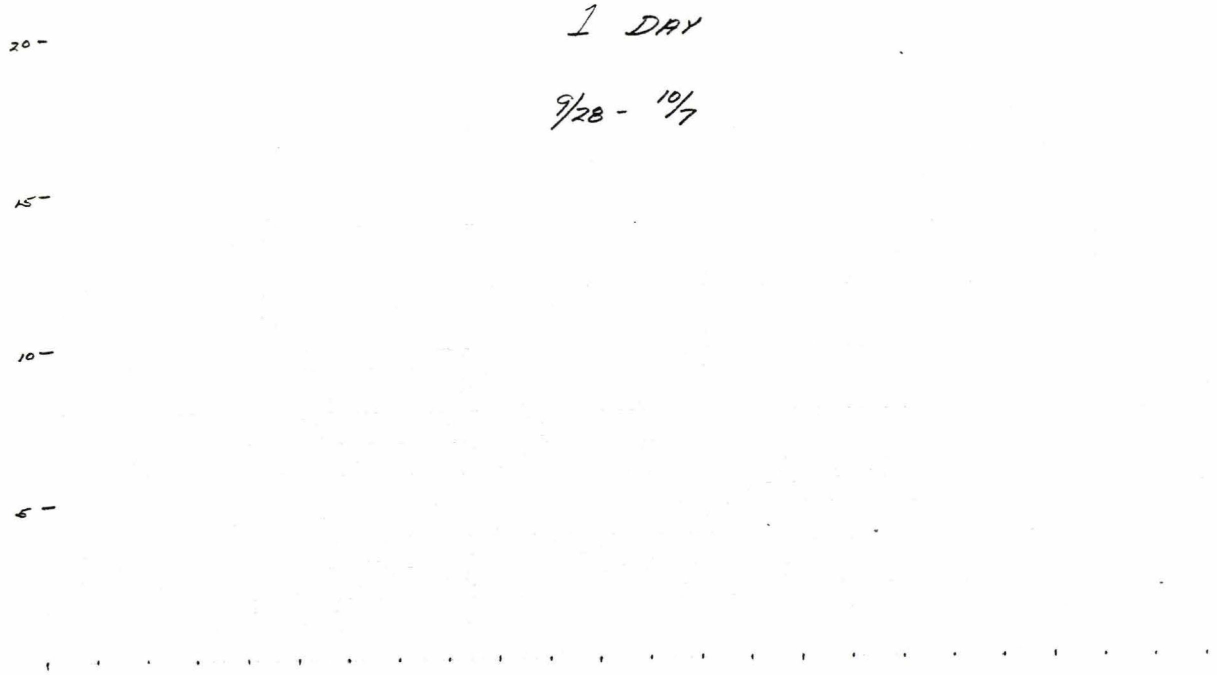
TEPEE C-5

BI 0-30
TEMP 40-65
RH 15-40
WS 5-10
1HR FM 5-30
10 HR FM 5-30



TEPEE C-8

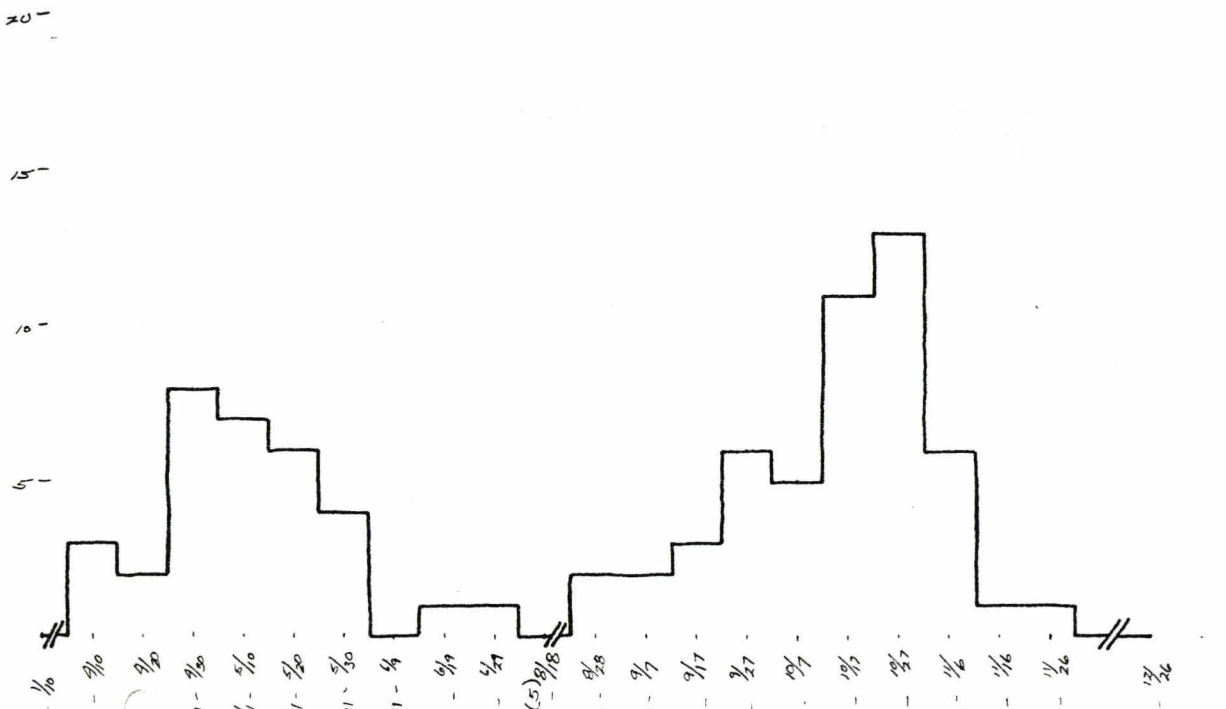
BI 0-30
TEMP 40-65
RH 15-40
WS 5-10
1HR FM 5-15
* 10 HR FM 10-25


1 DAY

9/28 - 10/7

TEPEE C-7

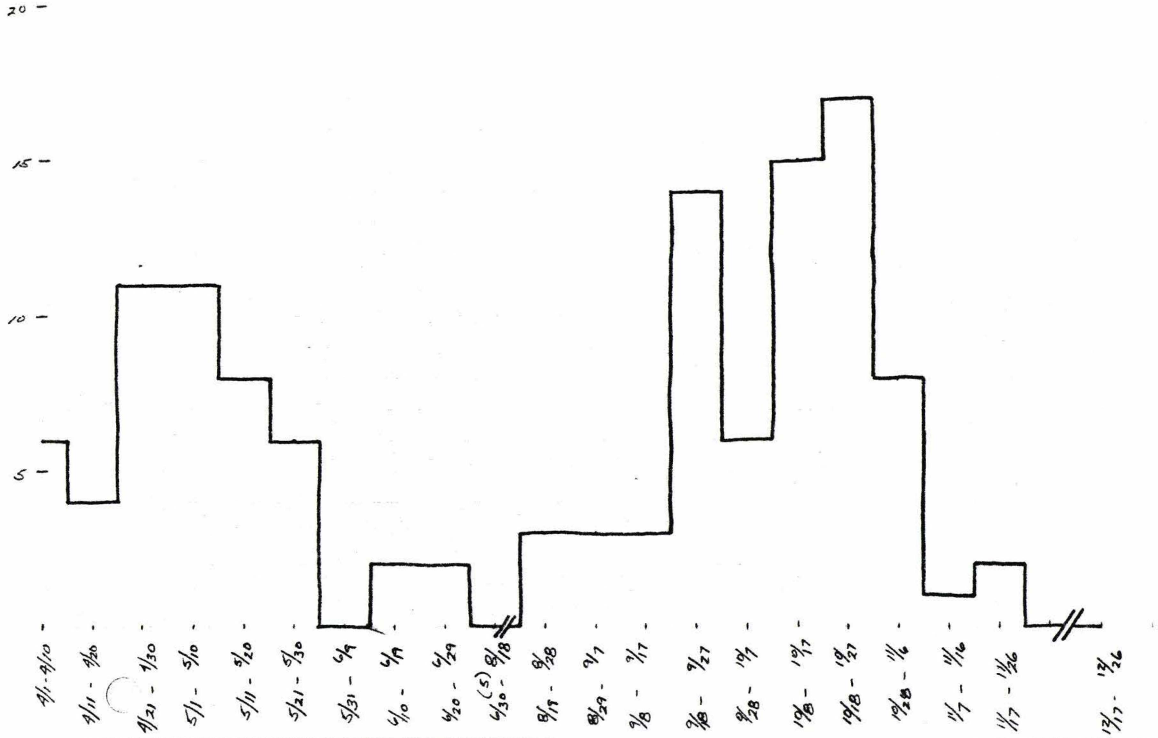
BI 0-30
TEMP 40-65
RH 15-40
WS 5-10
*1HR FM 5-15
10 HR FM 5-30



TEPEE C-10

compare to
#7

BI
TEMP
RH
* WS
1HR FM
10HR FM



TEPEE C-9

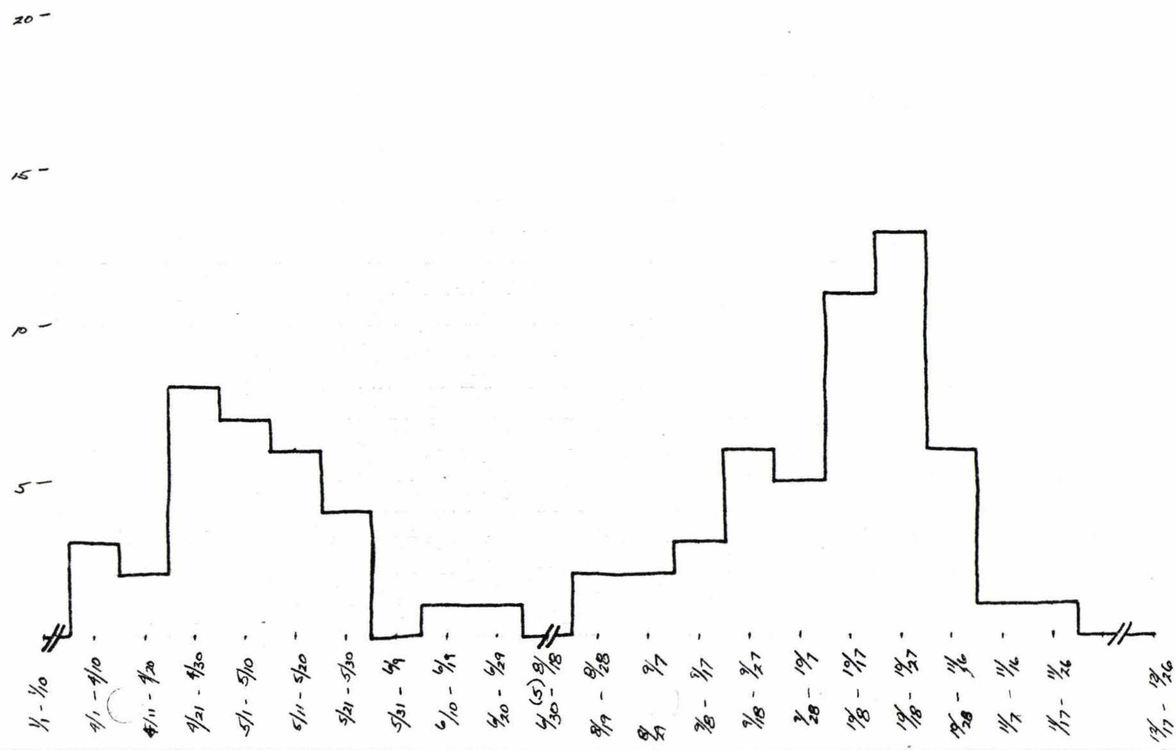
BI 0-30
TEMP 40-65
RH 15-40
WS 5-10
1HRFM 5-15
* 10HR FM 10-15

1 DAY.

9/28 - 10/7

TEPEE C-12

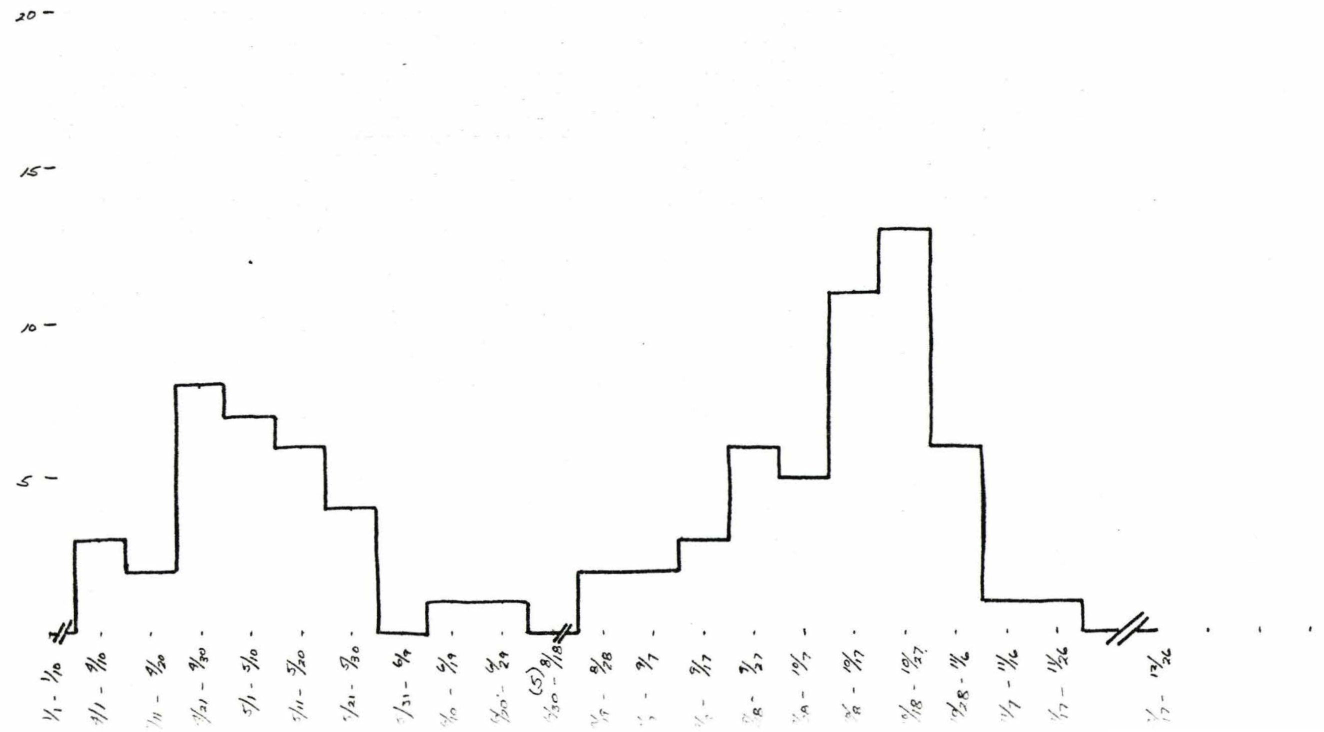
BI 0-30
TEMP 40-65
RH 10-40
WS 5-10
1HR FM 5-15
10HR FM 5-15



TEPEE C-11

Compare to
9

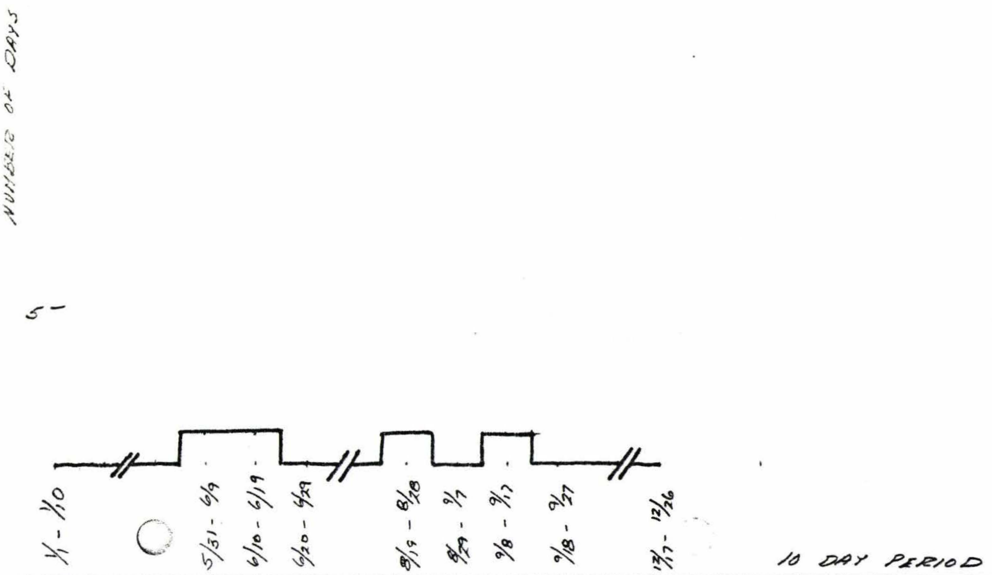
BI 0-30
TEMP 40-65
RH 15-40
WS 5-10
1HR FM 5-15
* 10HR FM 5-15



HOT SPRINGS C-1

TOTAL NUMBER OF DAYS IN EACH 10 DAY PERIOD, FOR 10 YEARS.

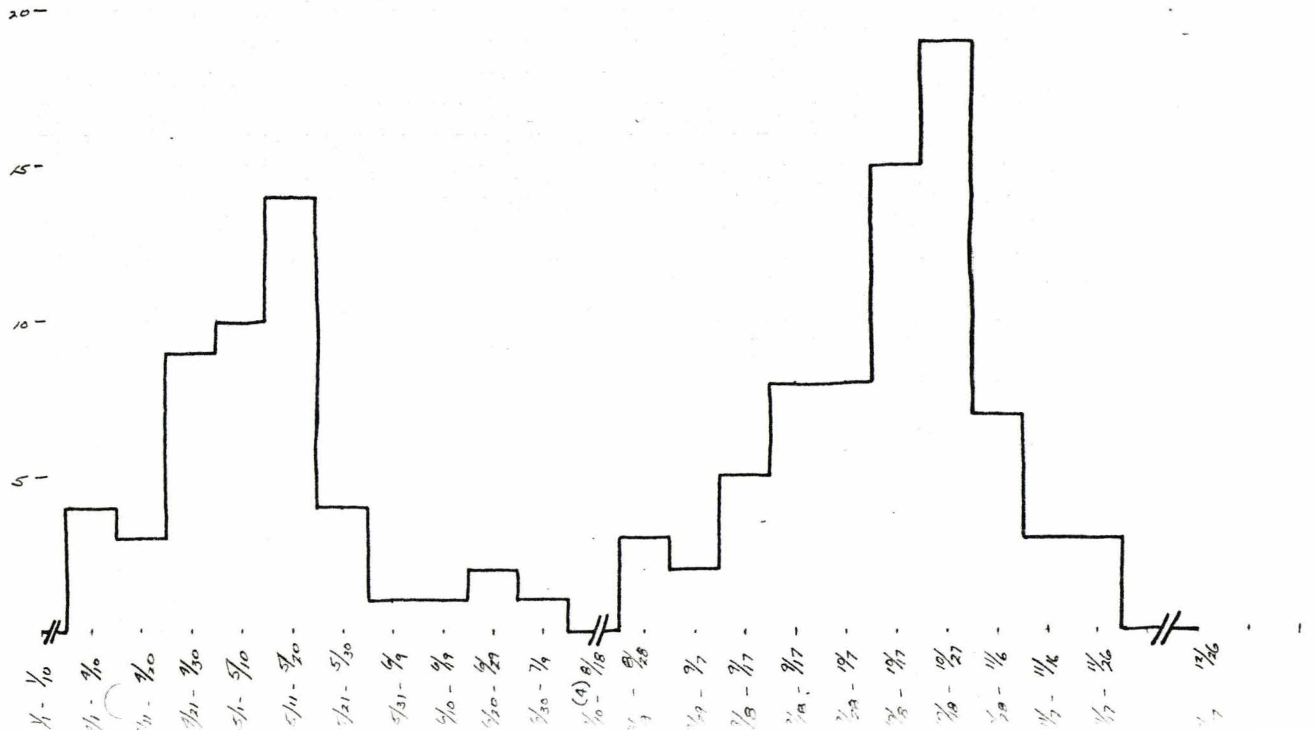
BI 0-30
TEMP 65-85
RH 15-50
WS 5-10
1 HR FM 10-25
10 HR FM 10-30



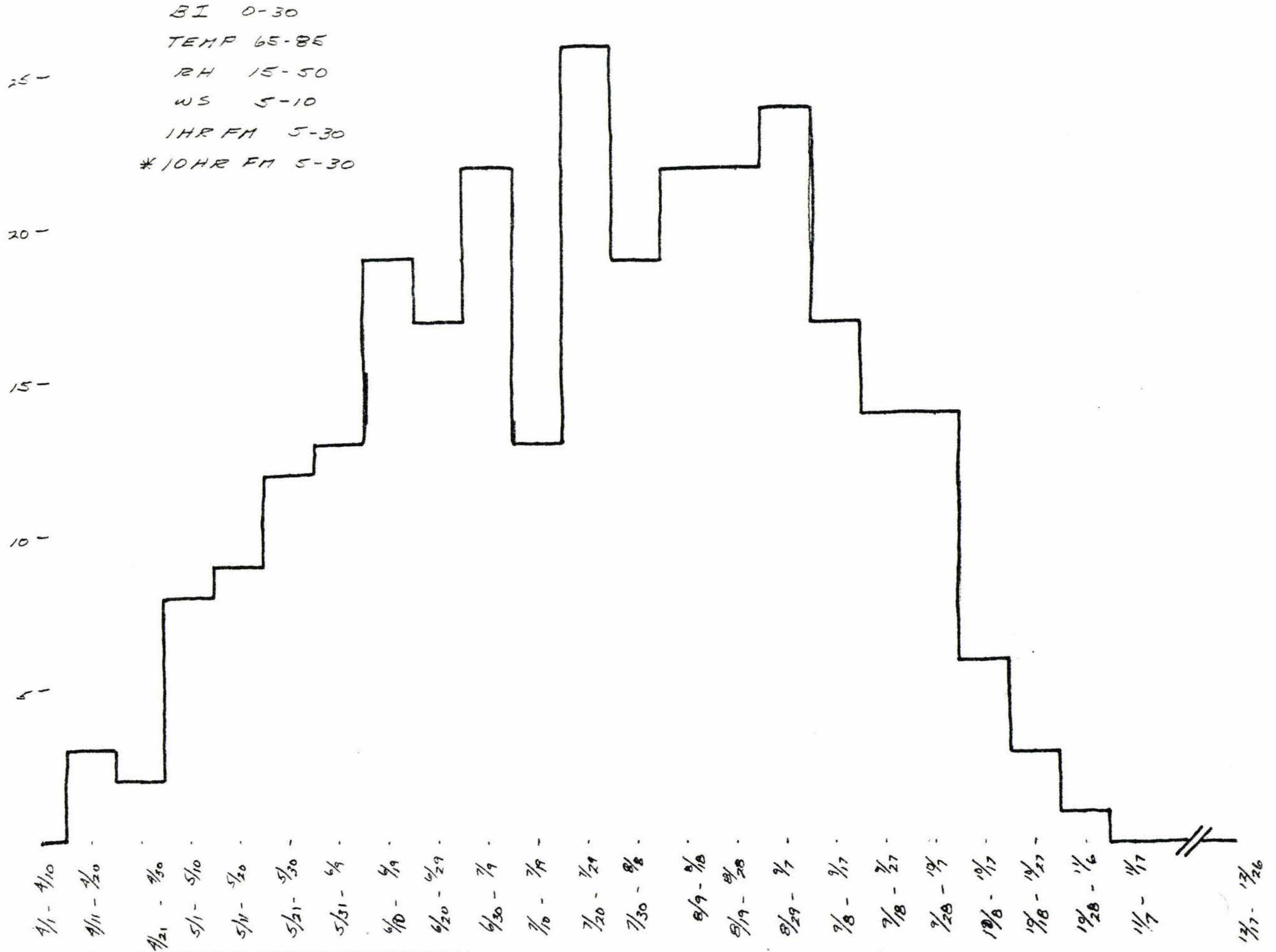
TEPEE C-13

compare to #4

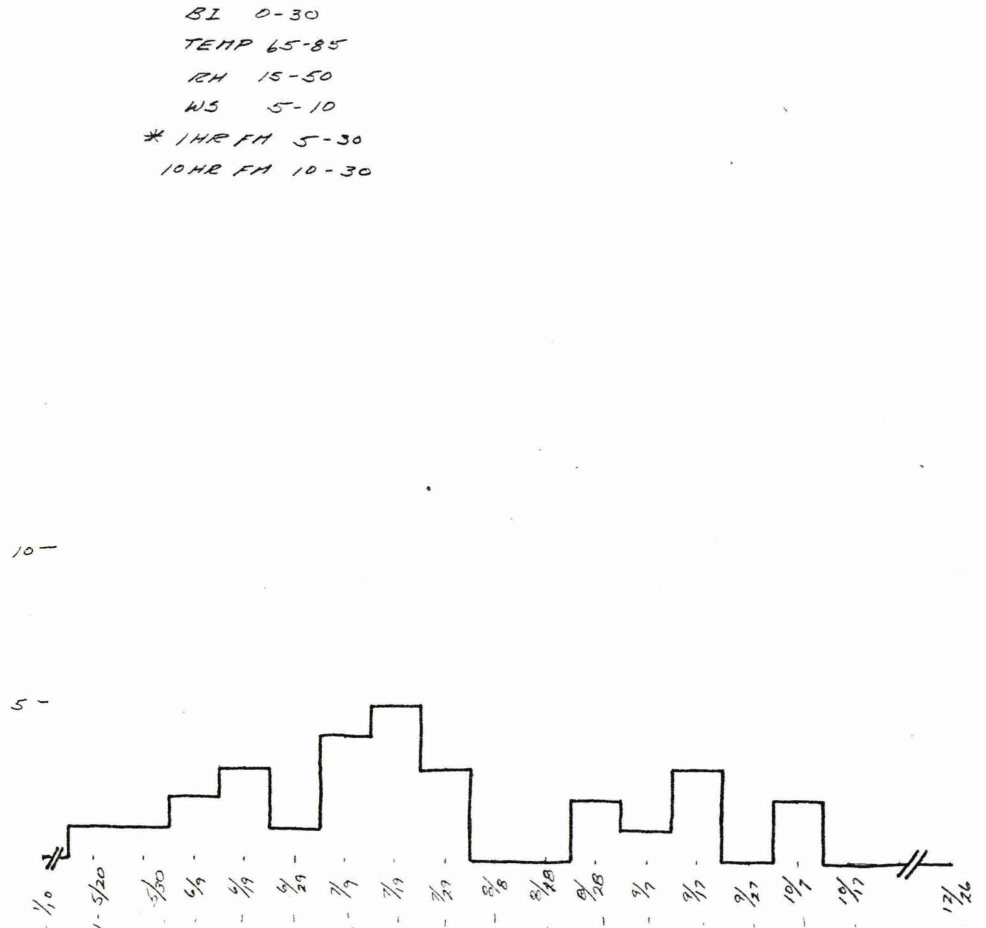
BI 0-30
TEMP 40-65
RH 15-50
WS 5-10
1 HR FM 5-10
10 HR FM 5-10



Hot Springs C-3

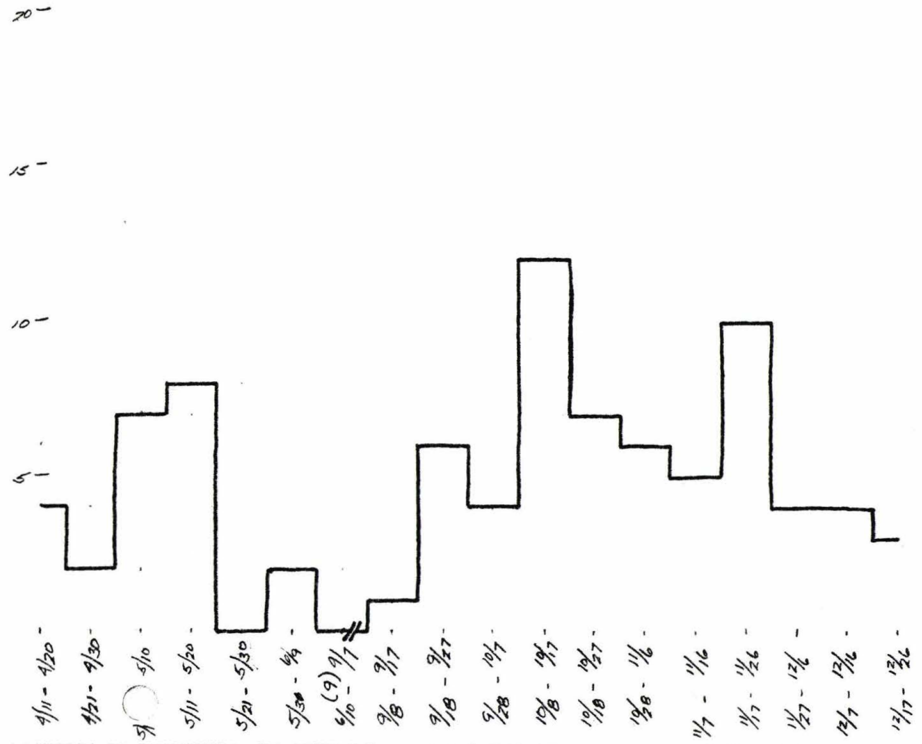


Hot Springs C-2



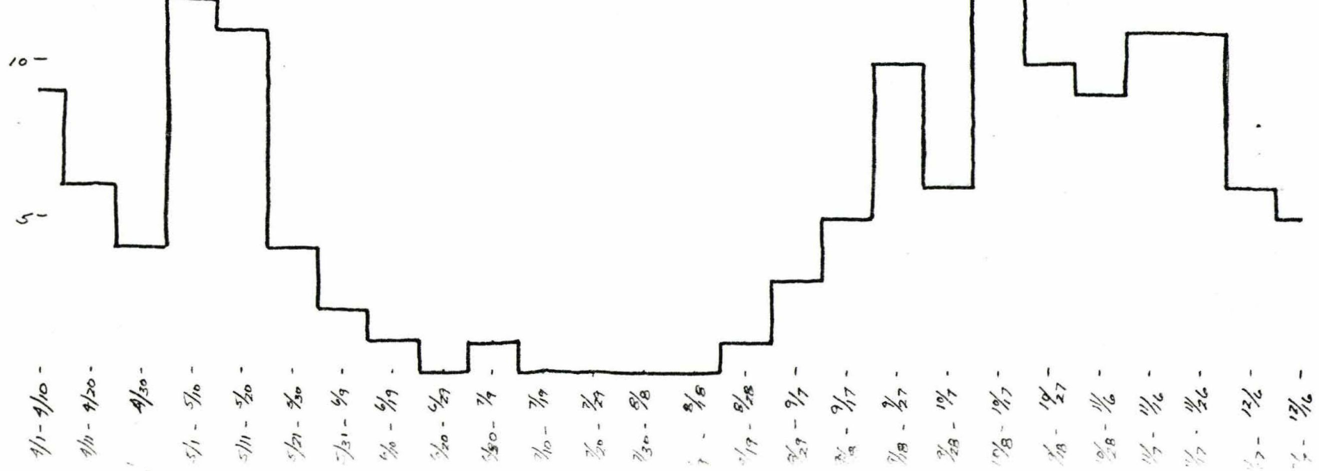
HOT SPRINGS C-5

BI 0-30
TEMP 40-65
RH 15-40
WS 5-10
1 HR FM 5-30
10 HR FM 5-30



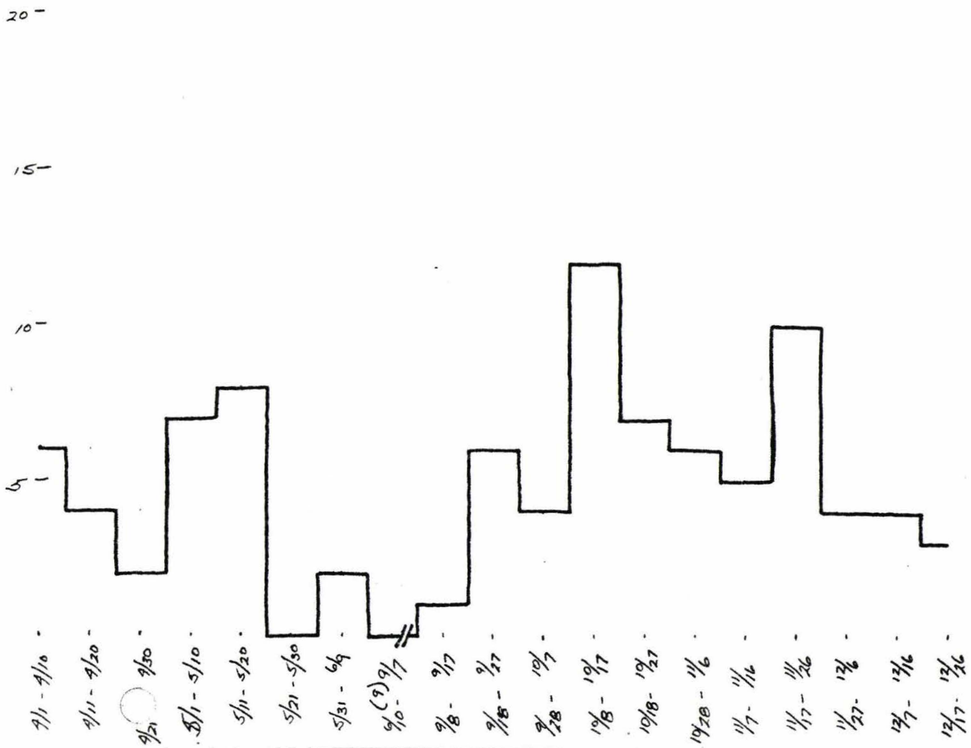
HOT SPRINGS C-4

BI 0-30
* TEMP 40-65
RH 15-50
WS 5-10
1 HR FM 5-30
10 HR FM 5-30



HOT SPRINGS C-7

BI 0-30
TEMP 40-65
RH 15-40
WS 5-10
*1HR FM 5-15
10 HR FM 5-30



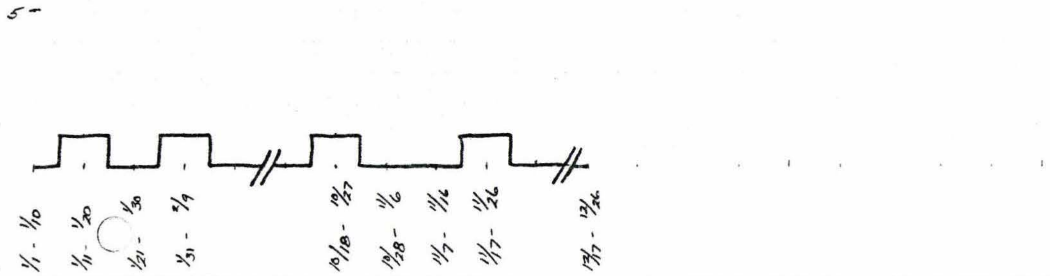
HOT SPRINGS C-6

BI 0-30
TEMP 40-65
RH 15-40
WS 5-10
*1HR FM 10-25
10 HR FM 5-30

No DAYS

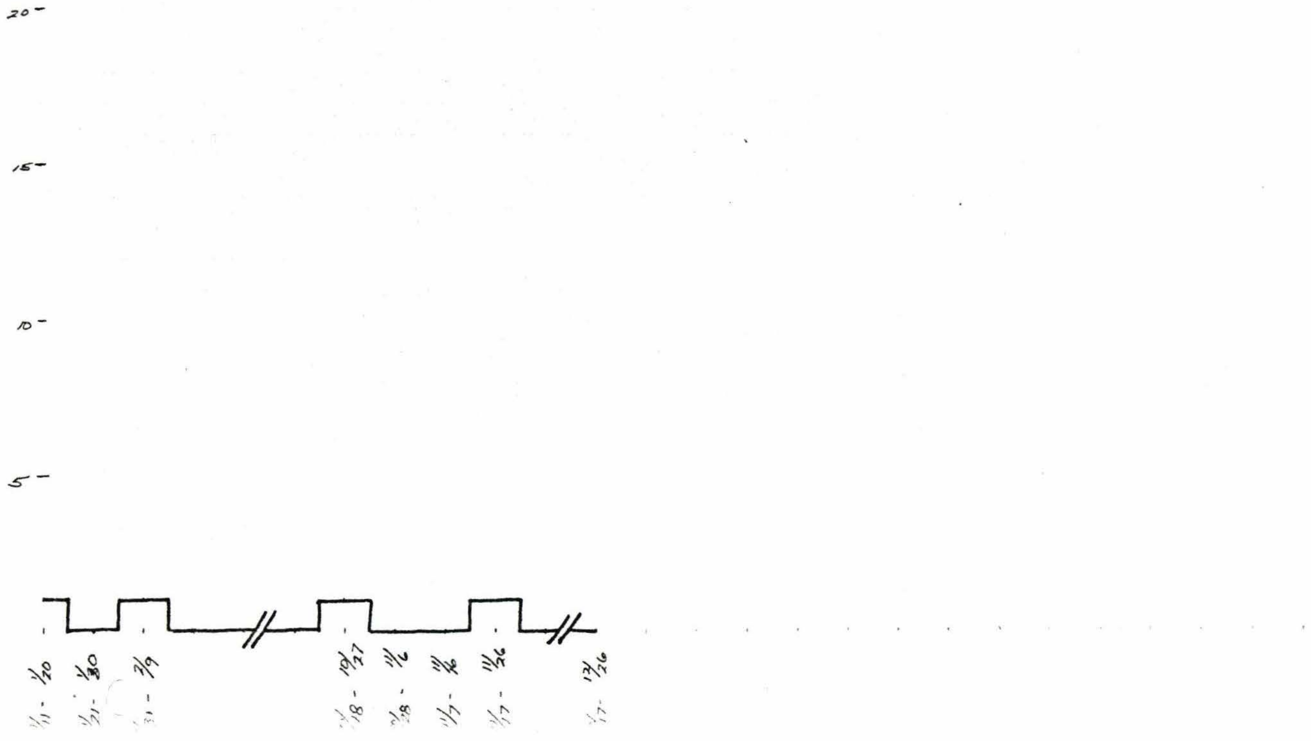
HOT SPRINGS C-9

BI 0-30
TEMP 40-65
RH 15-40
WS 5-10
1 HR FM 5-15
* 10 HR FM 10-15



HOT SPRINGS C-8

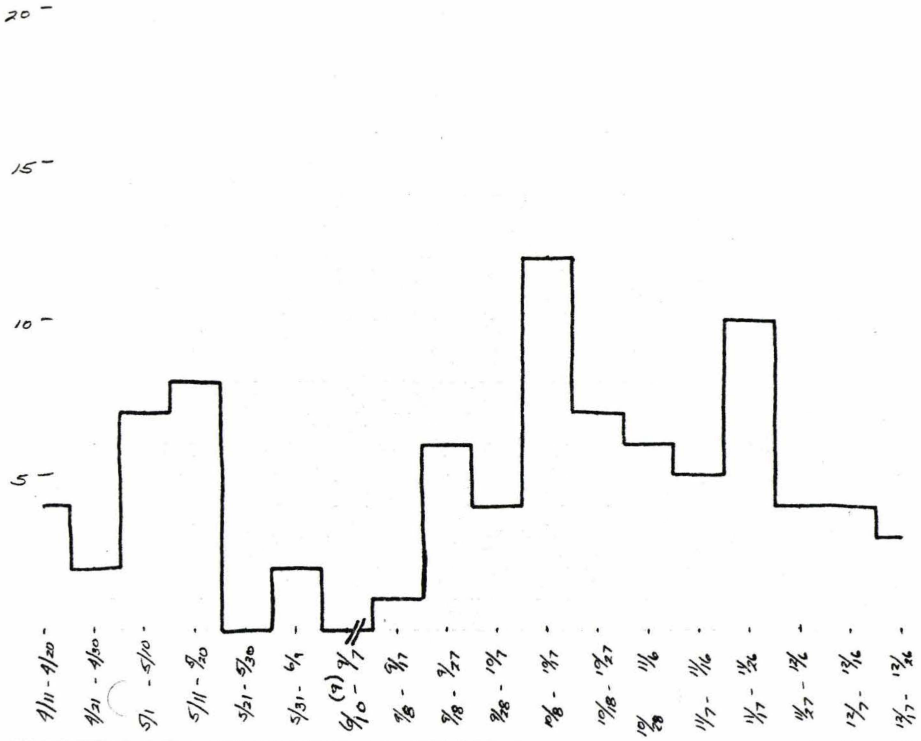
BI 0-30
TEMP 40-65
RH 15-40
WS 5-10
1 HR FM 5-15
*10 HR FM 10-25



HOT SPRINGS C-11

compare to
#9

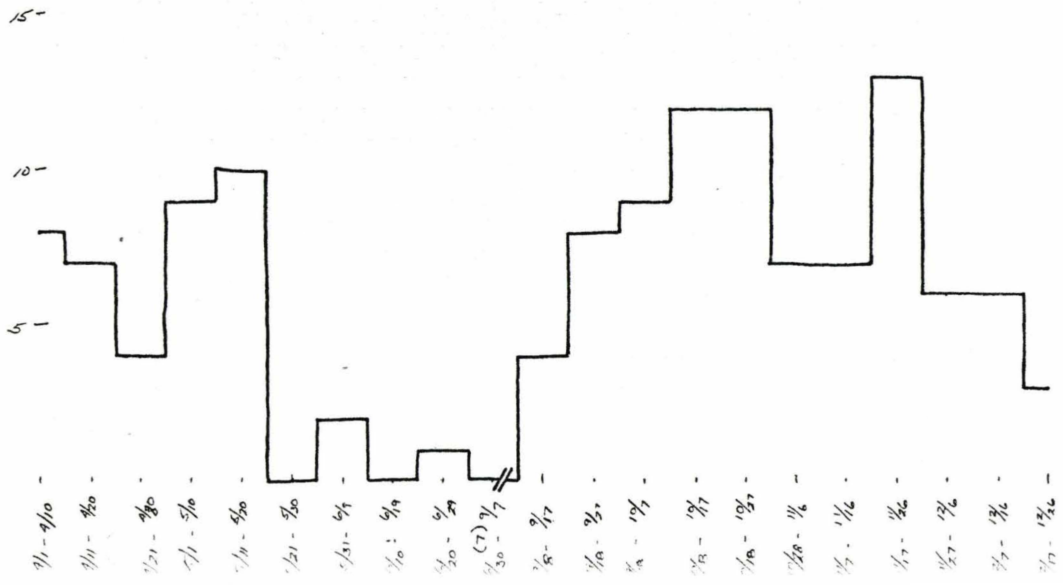
BI 0-30
TEMP 40-65
RH 15-40
WS 5-10
1HR FM 5-15
10 HR FM 5-15



HOT SPRINGS C-10

compare to
#7

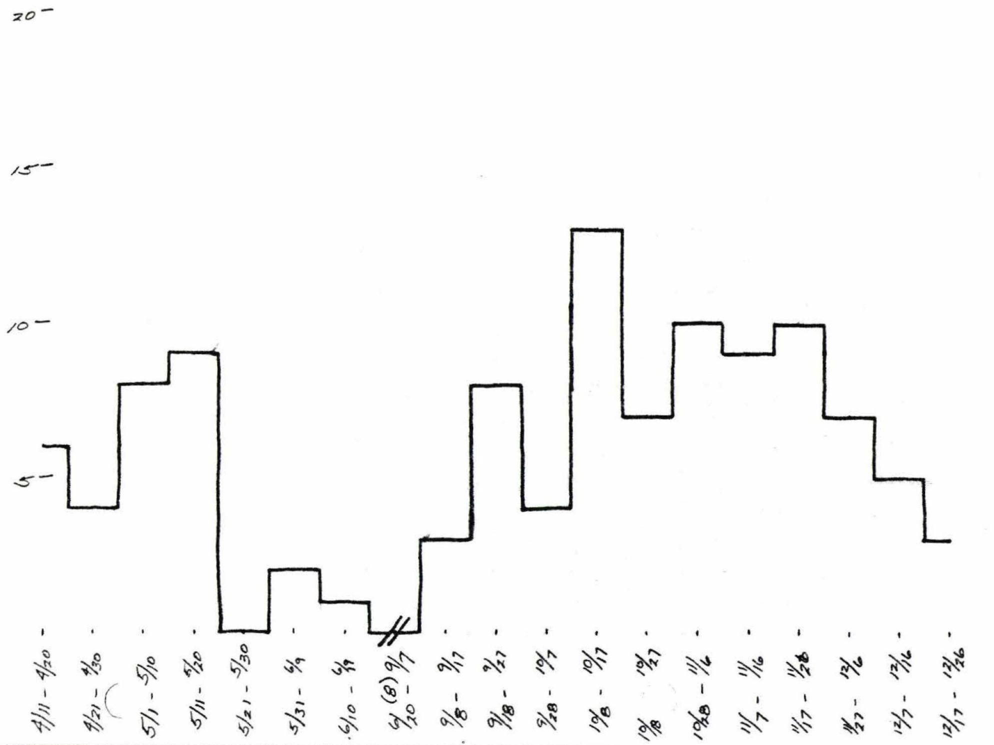
BI
TEMP 40-65
RH
WS
1HR FM
10 HR FM



HOT SPRINGS C-13

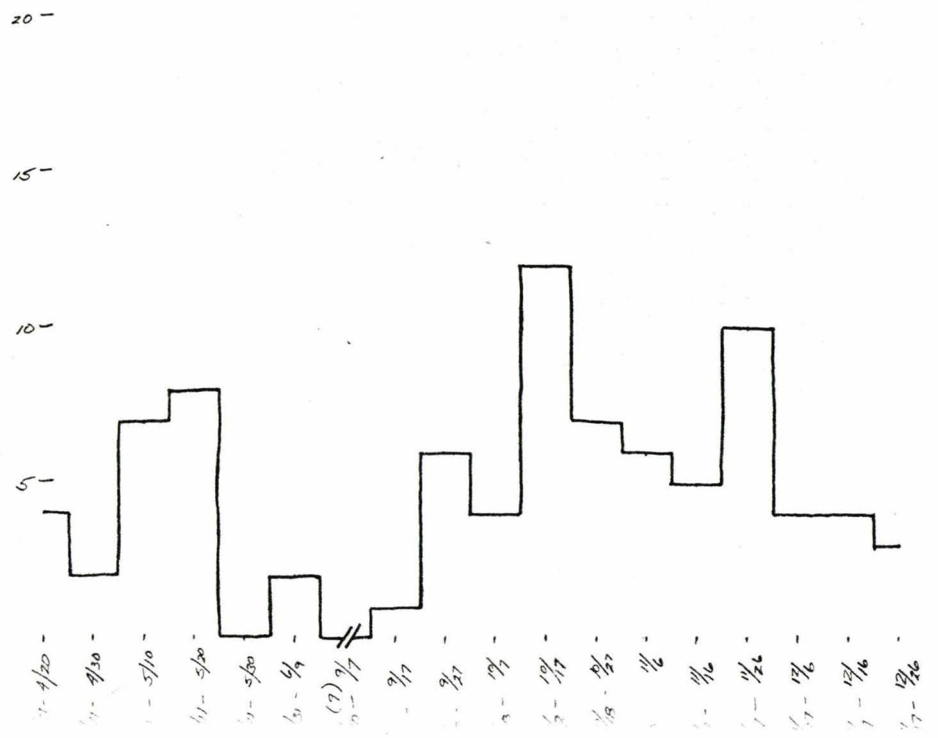
compare to
A

BI 0-30
TEMP 40-65
RH 15-50
WS 5-10
1HR FM 5-10
10HR FM 5-10



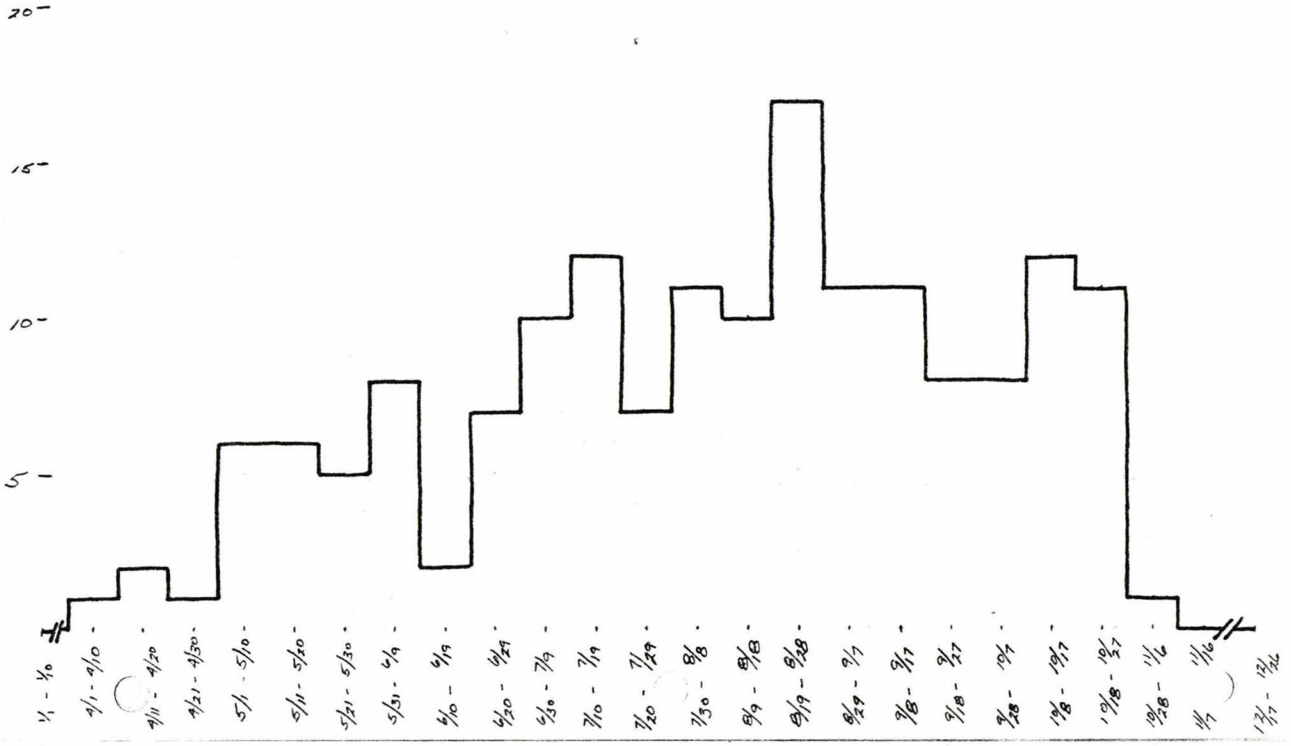
HOT SPRINGS C-12

BI 0-30
TEMP 40-65
RH 10-40
WS 5-10
1HR FM 5-15
10HR FM 5-15



NEMO E-6

BI 0-25
TEMP 60-90
RH 15-40
WS 3-8
1 HR FM 5-25
10 HR FM 5-20



NEMO E-1 TO E-5

BI 0-25
TEMP 70-80
RH 20-30
WS 3-8
1 HR FM 15-25
10 HR FM 15-20

E-2
TEMP 60-90

E-3
1 HR FM 10-30

E-4
RH 15-40

E-5
1 HR FM 5-25

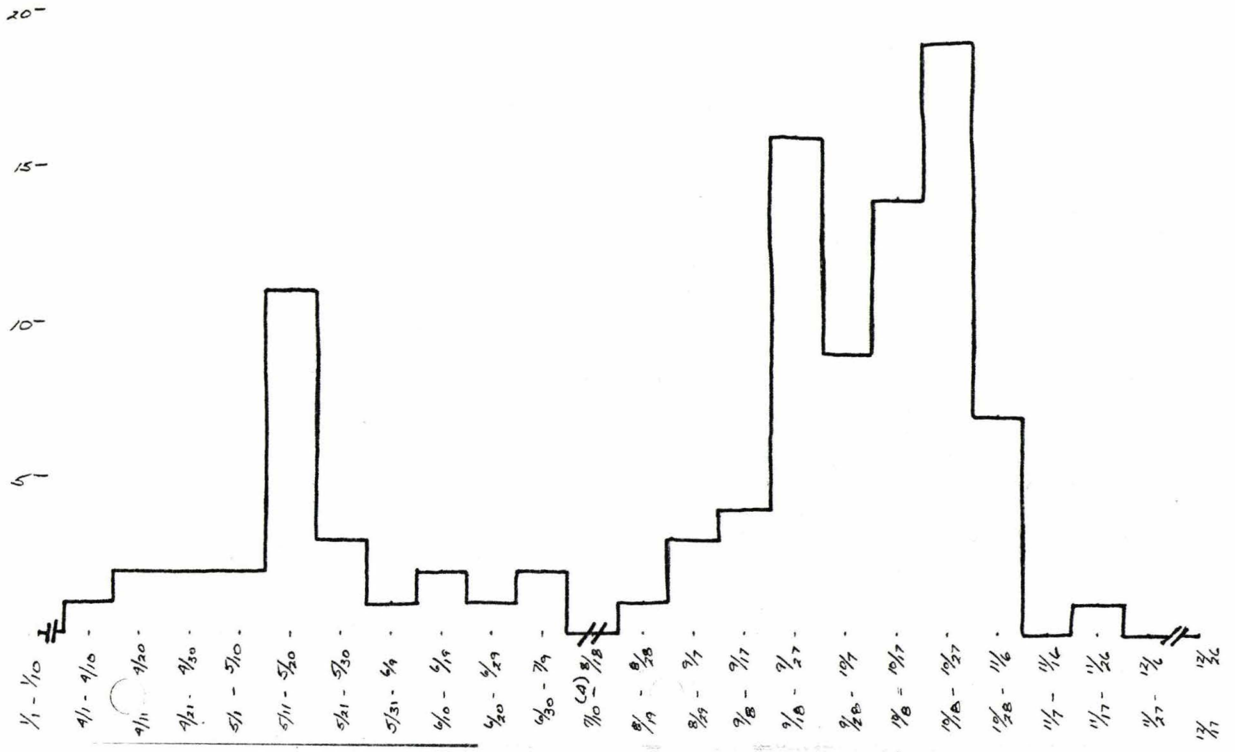
NUMBER OF DAYS

NO DAYS

TOTAL DAYS IN EACH 10
DAY PERIOD FOR 10 YEARS

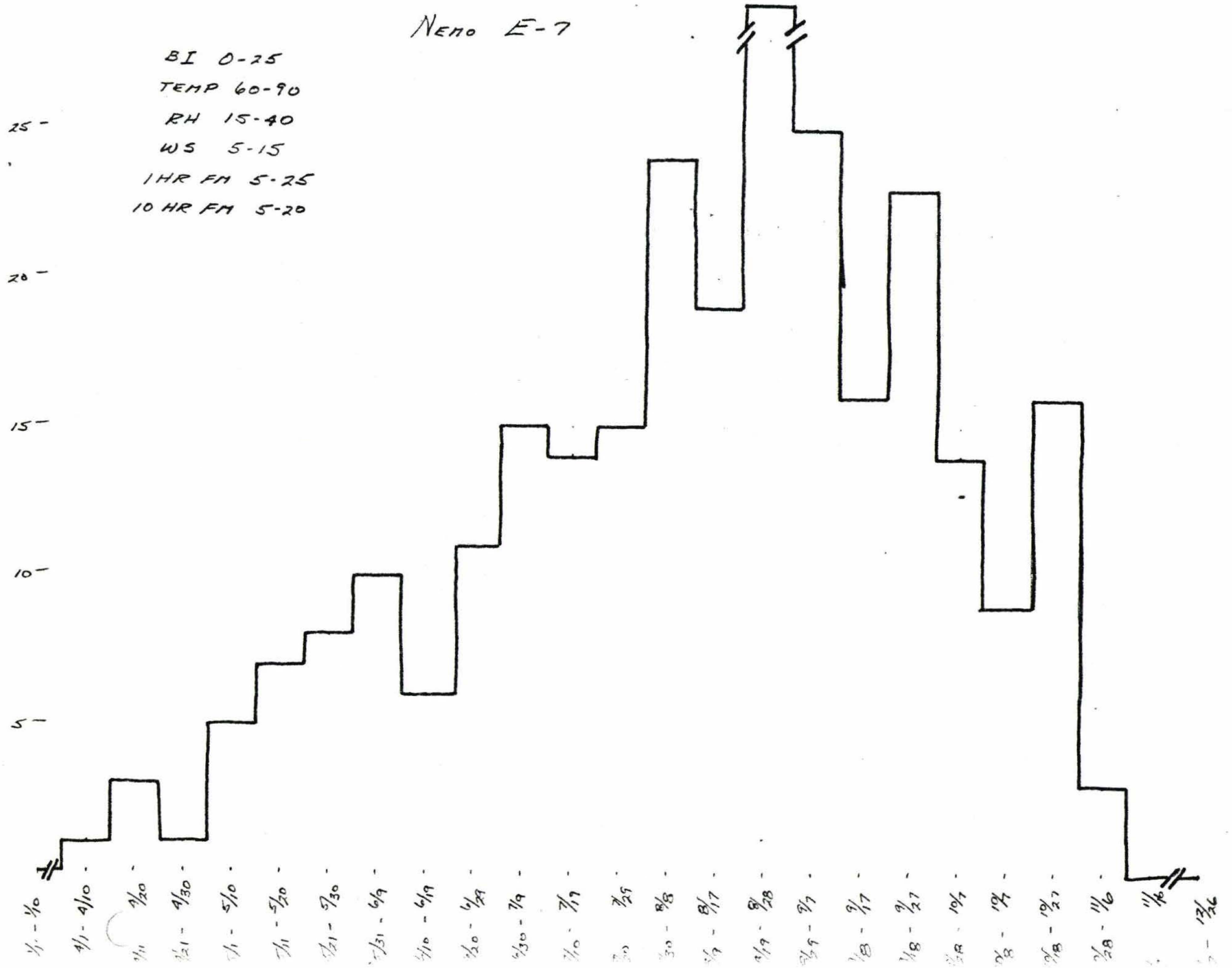
NEMO E-8

BI 0-25
TEMP 40-65
RH 15-40
WS 5-15
1HR FM 5-25
10 HR FM 5-20



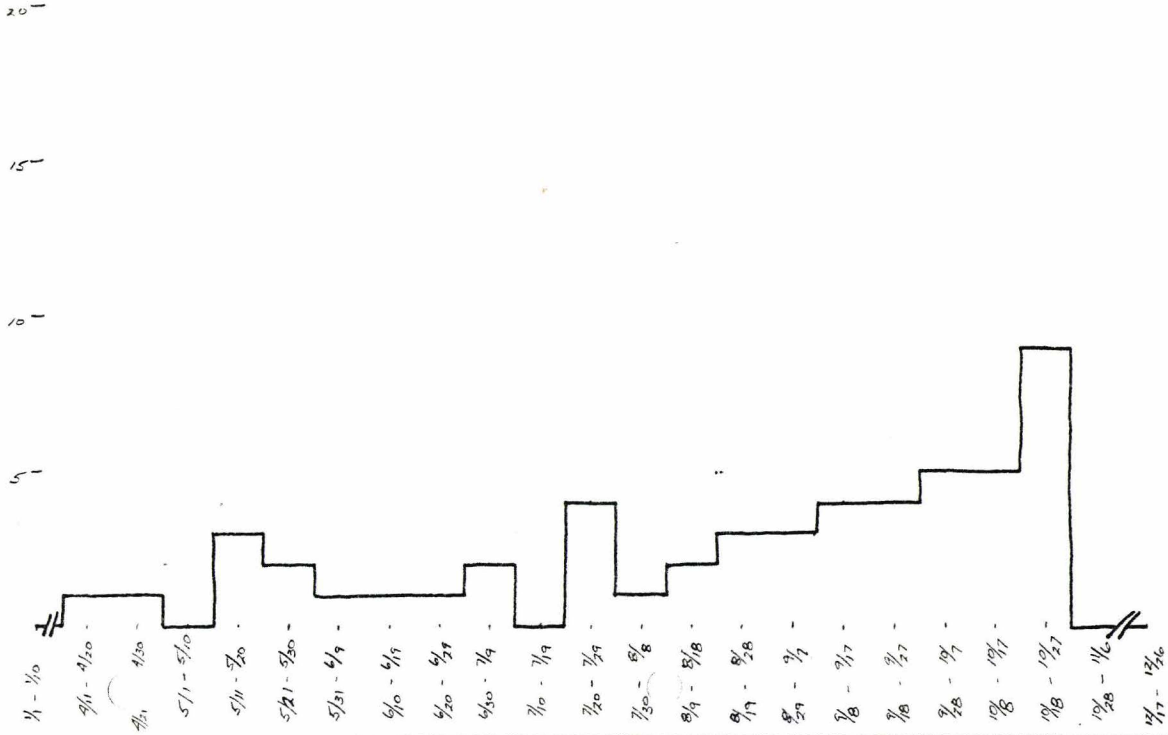
NEMO E-7

BI 0-25
TEMP 60-90
RH 15-40
WS 5-15
1HR FM 5-25
10 HR FM 5-20



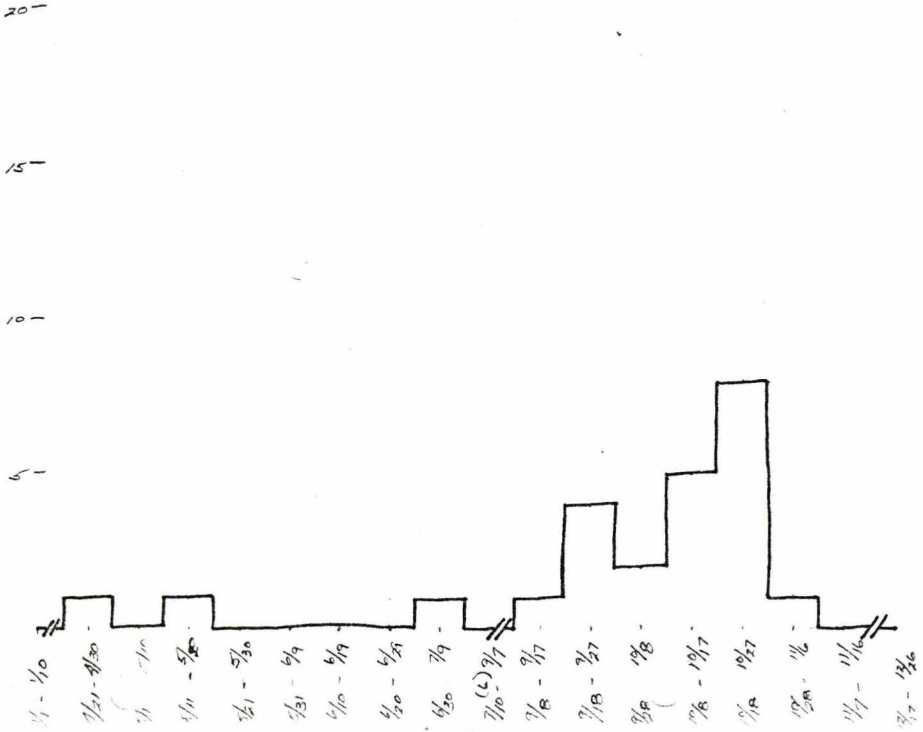
NEMO E-10

BI 0-25
TEMP 60-80
RH 20-30
WS 5-15
1 HR FM 5-25
10 HR FM 5-20



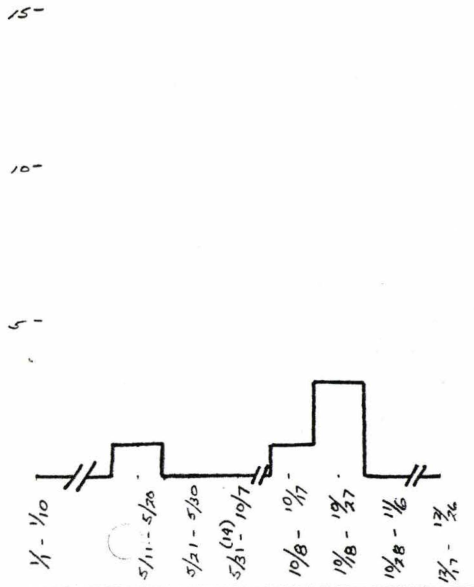
NEMO E-9

BI 0-25
TEMP 40-65
RH 20-30
WS 5-15
1 HR FM 5-25
10 HR FM 5-20



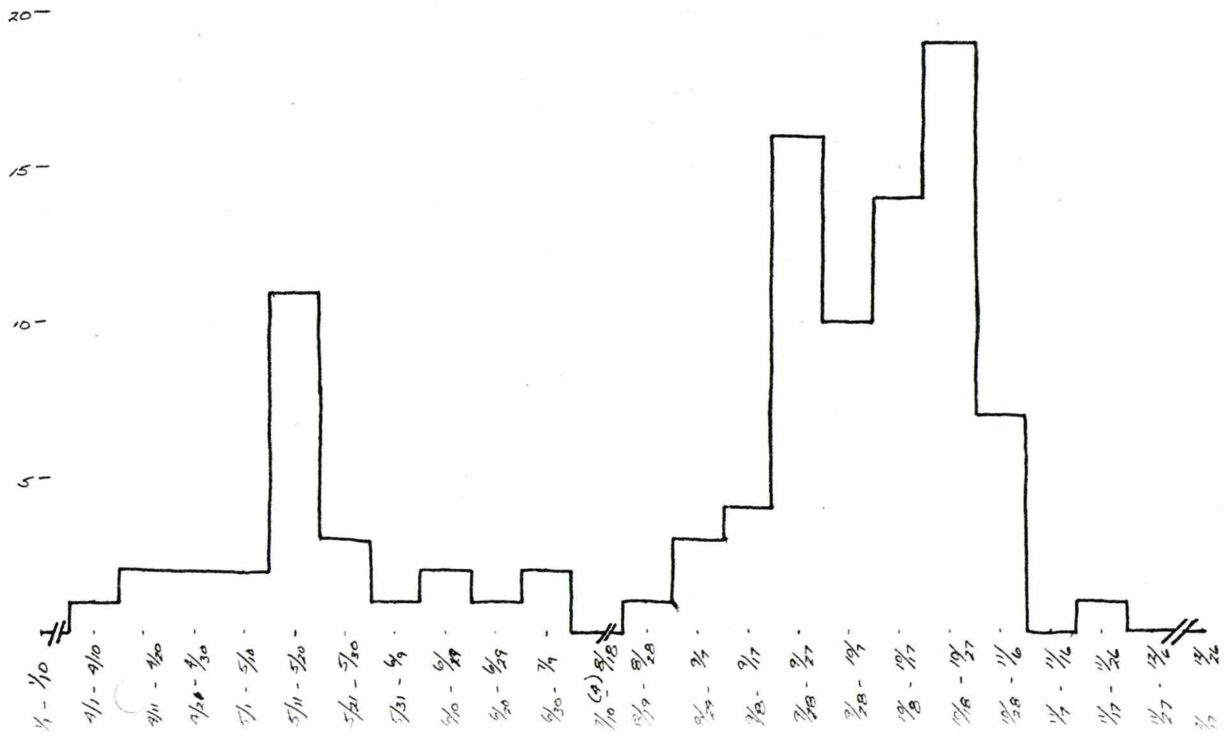
NEMO E-12

BI 0-25
TEMP 40-65
RH 10-25
WS 5-15
1 HR FM 5-25
10 HR FM 5-20



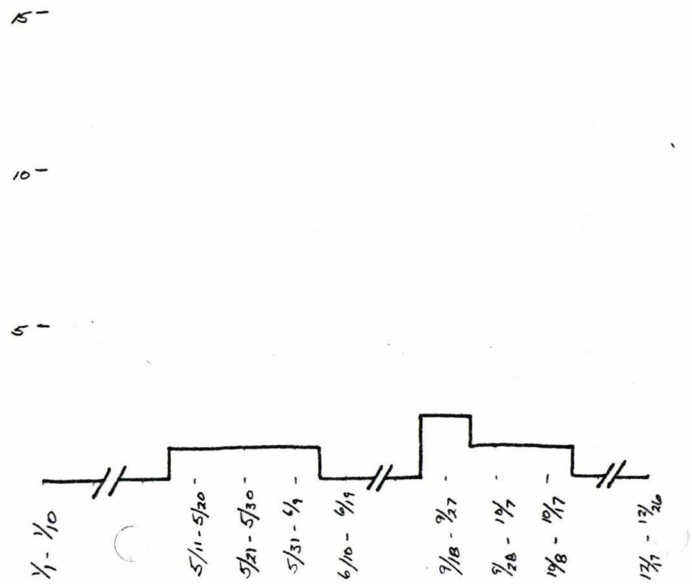
NEMO E-11

BI 0-25
TEMP 40-65
RH 15-40
WS 5-15
1 HR FM 5-25
10 HR FM 5-15



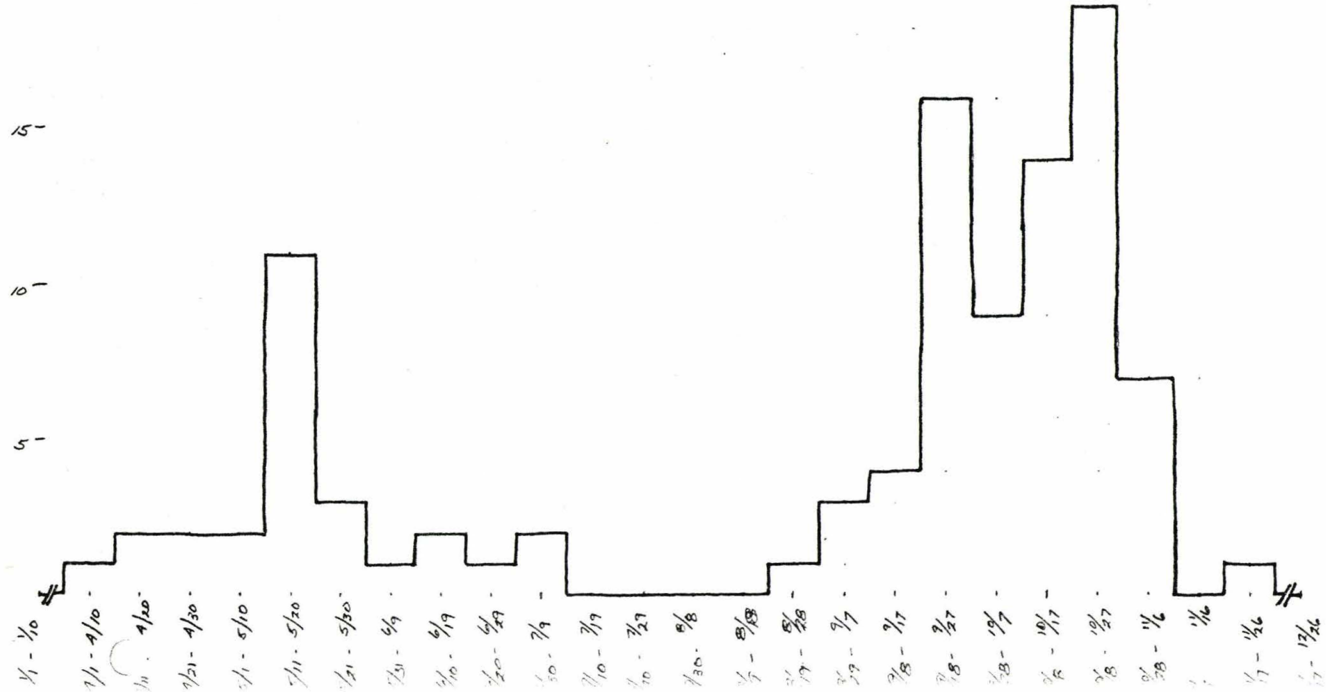
NEMO E-14

BI 0-25
TEMP 40-65
RH 15-40
WS 5-15
1HR FM 5-15
10HR FM 10-15

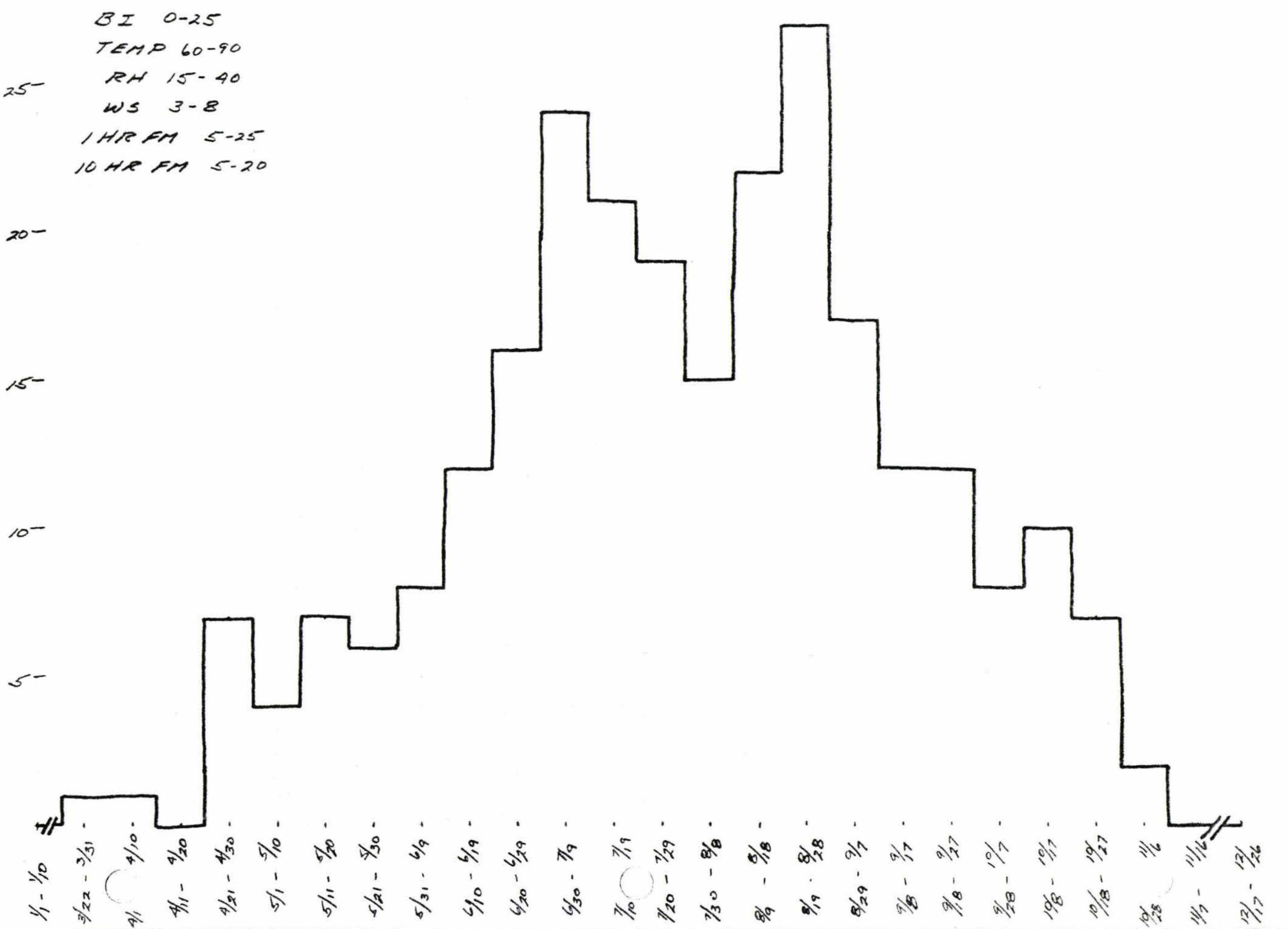


NEMO E-13

BI 0-25
TEMP 40-65
RH 15-40
WS 5-15
1HRFM 5-15
10 HR FM 5-20



TEPEE E-6



BI 0-25
TEMP 60-90
RH 15-40
WS 3-8
1 HR FM 5-25
10 HR FM 5-20

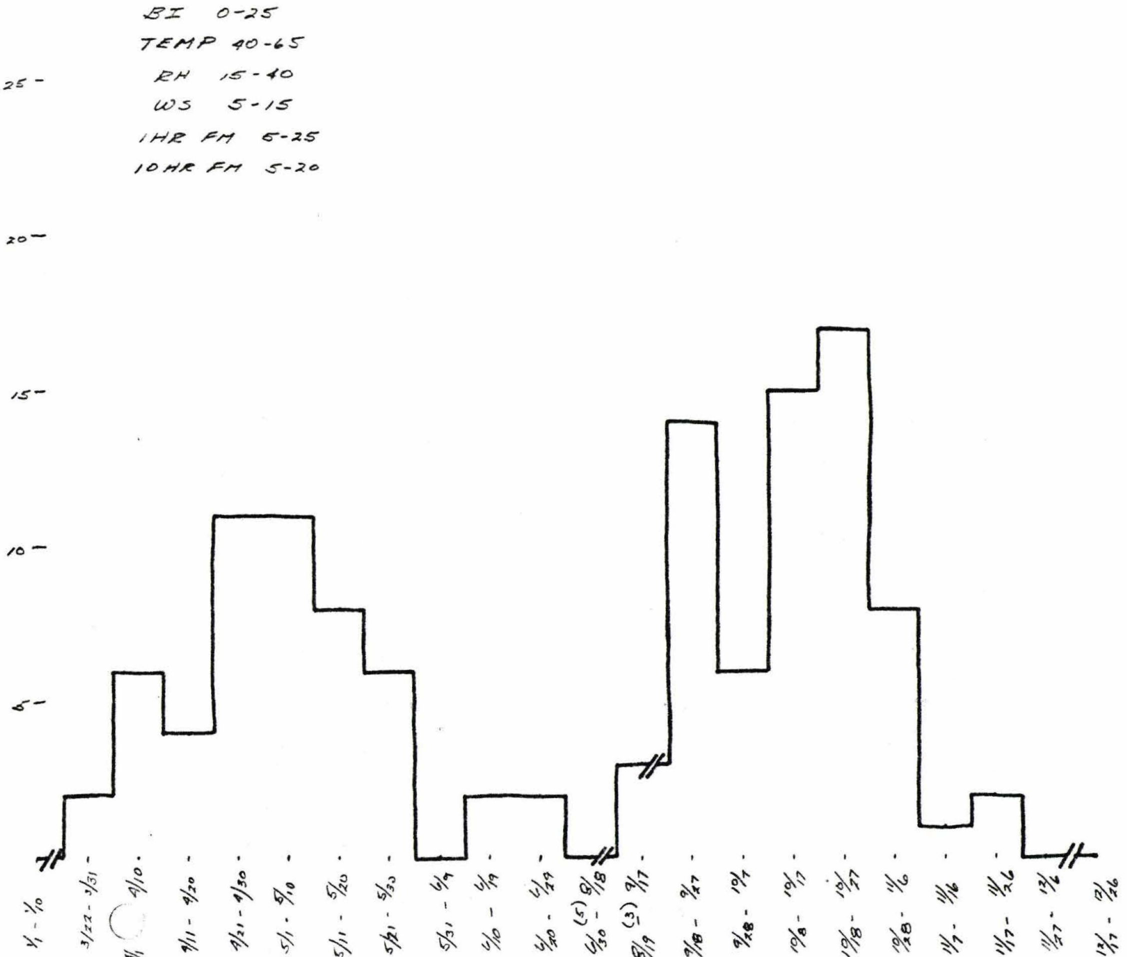
TEPEE E-1 TO E-5

BI 0-25
TEMP 70-90
RH 20-30
WS 3-8
1 HR FM 15-25
10 HR FM 15-20

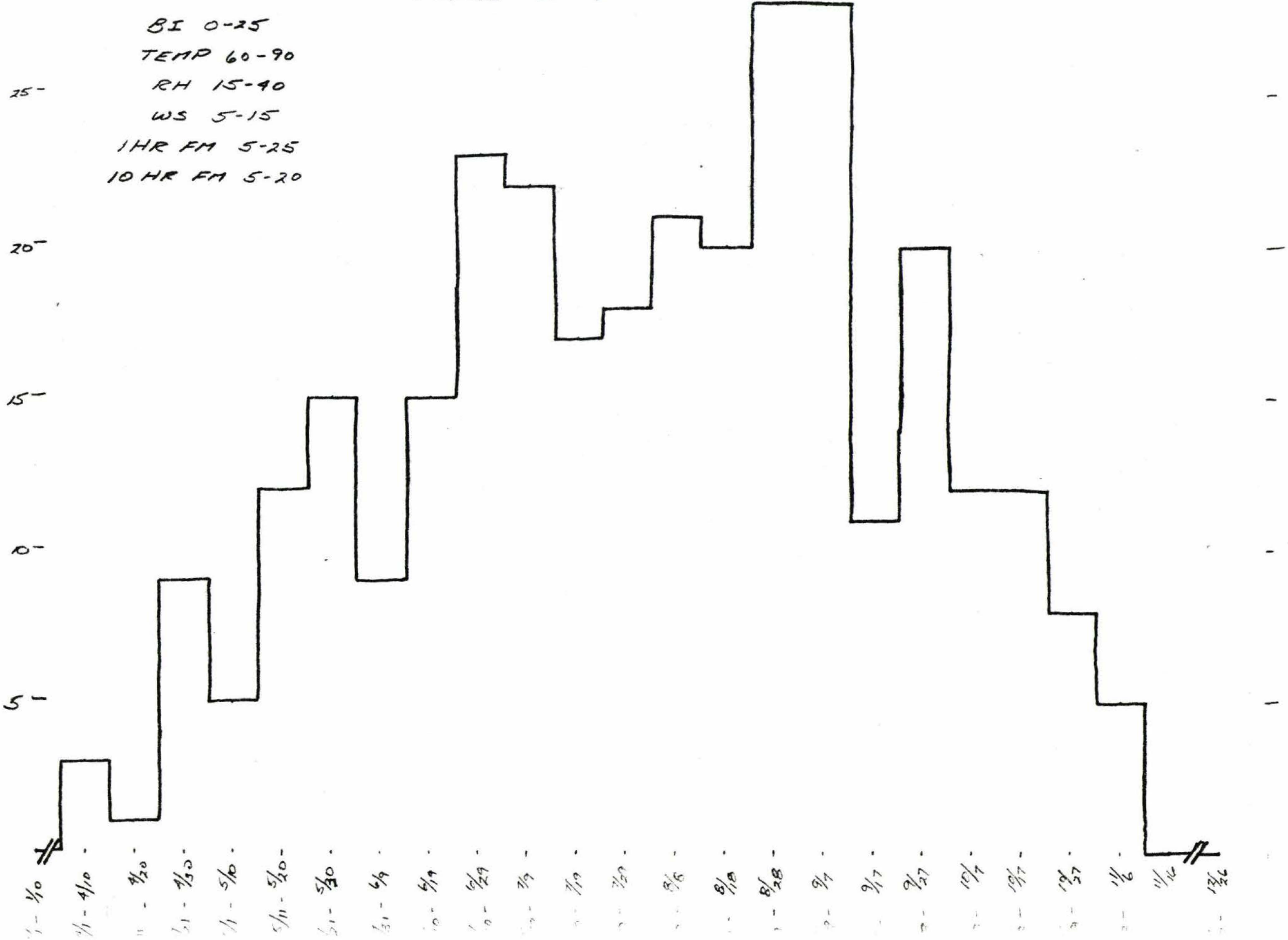
E-2	E-3	E-4	E-5
TEMP 60-90	1 HR FM 10-30	RH 15-40	1 HR FM 5-25

NO DAYS

TEPEE E-8

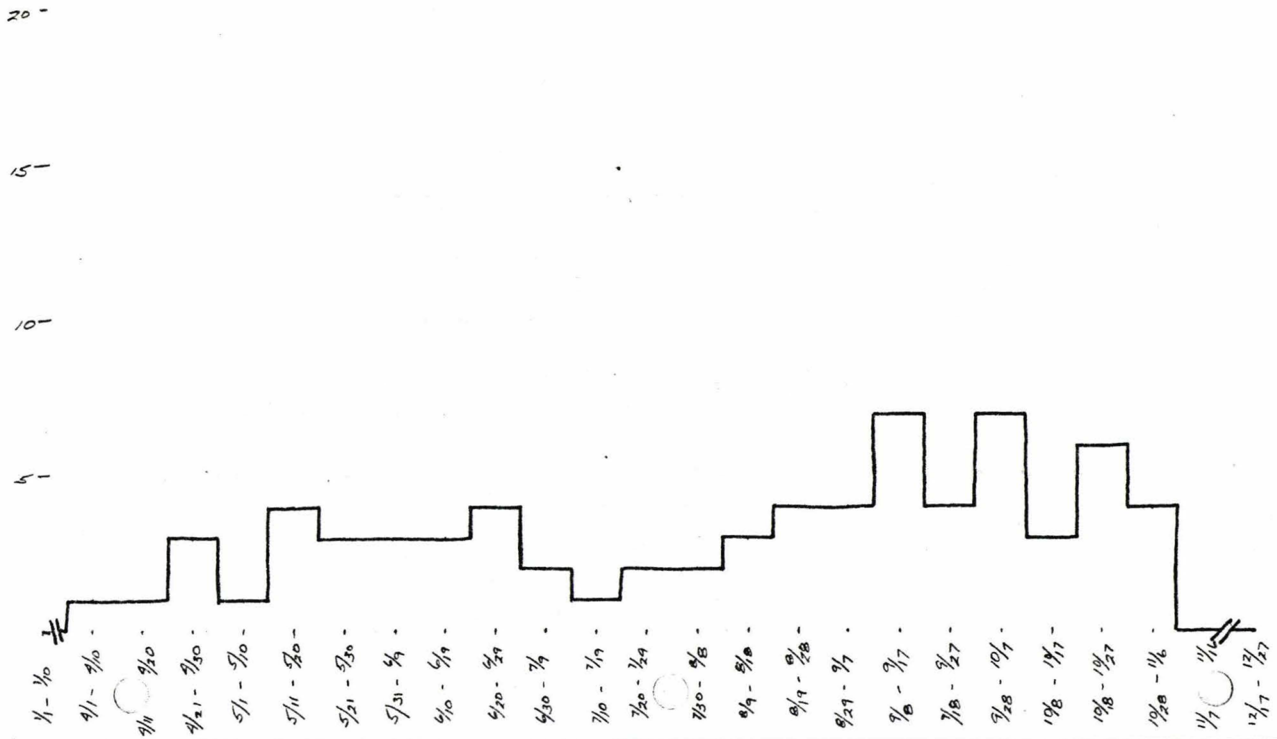


TEPEE E-7



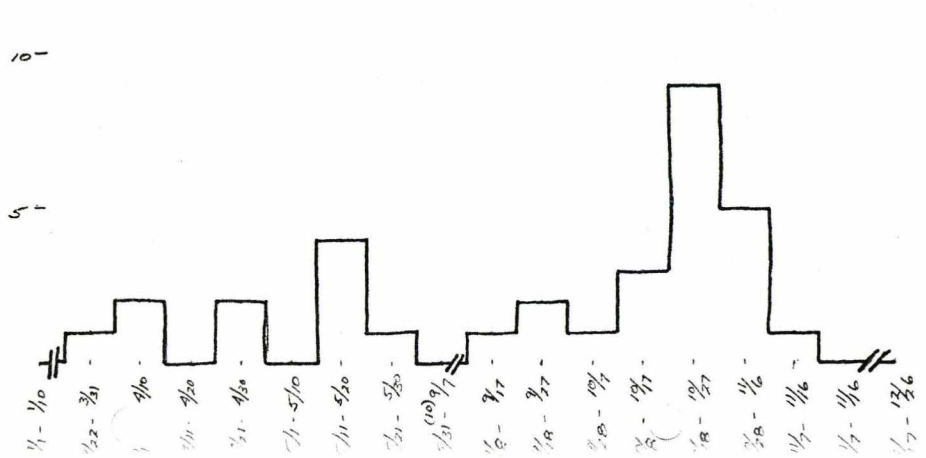
TEPEE E-10

BI 0-25
TEMP 60-80
RH 20-30
WS 5-15
1 HR FM 5-25
10 HR FM 5-20



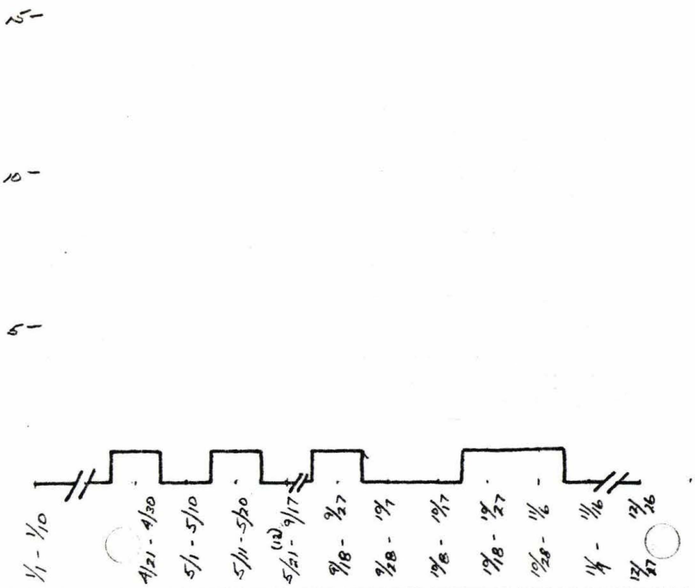
TEPEE E-9

BI 0-25
TEMP 40-65
RH 20-30
WS 5-15
1 HR FM 5-25
10 HR FM 5-20



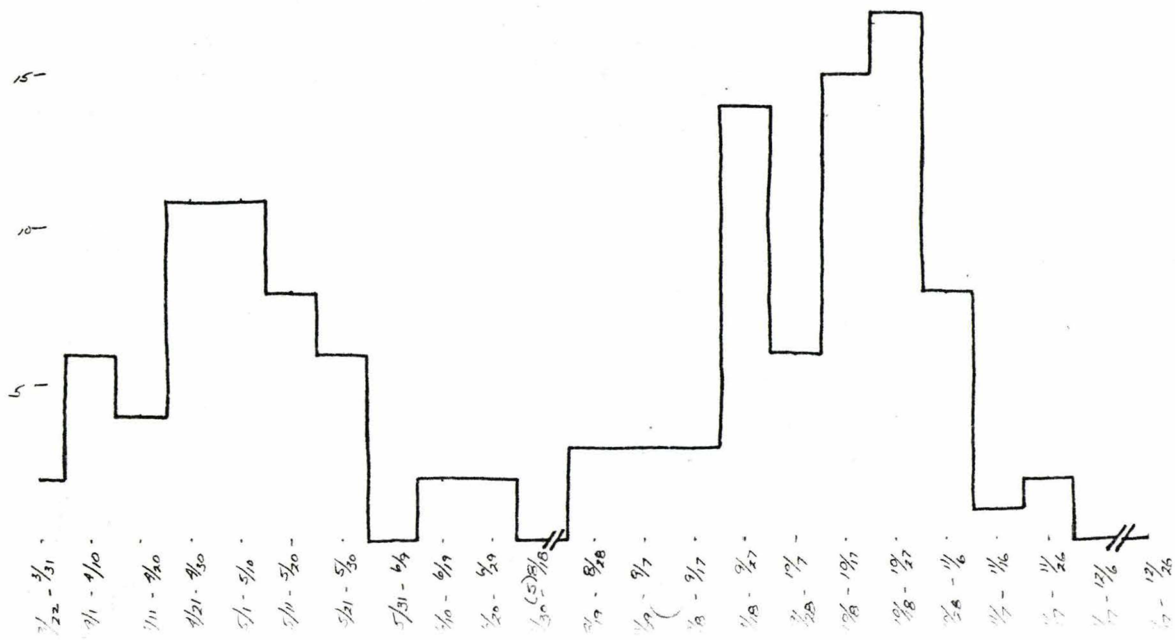
TEDEE E-12

BI 0-25
TEMP 40-65
RH 10-25
WS 5-15
1HR FM 5-25
10 HR FM 5-20



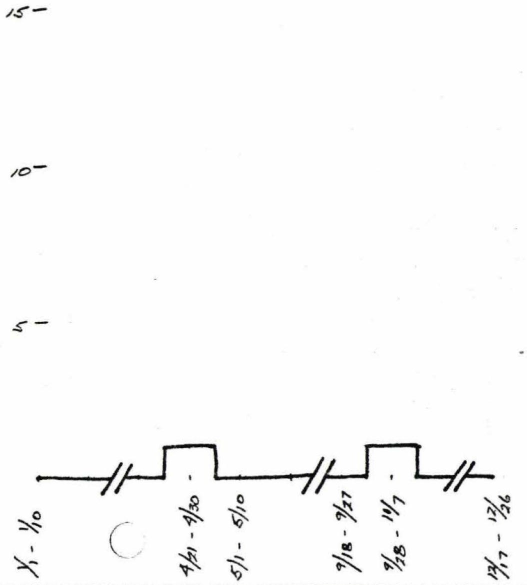
TEPEE E-11

BI 0-25
TEMP 40-65
RH 15-40
WS 5-15
1HRFM 5-25
10 HR FM 5-15



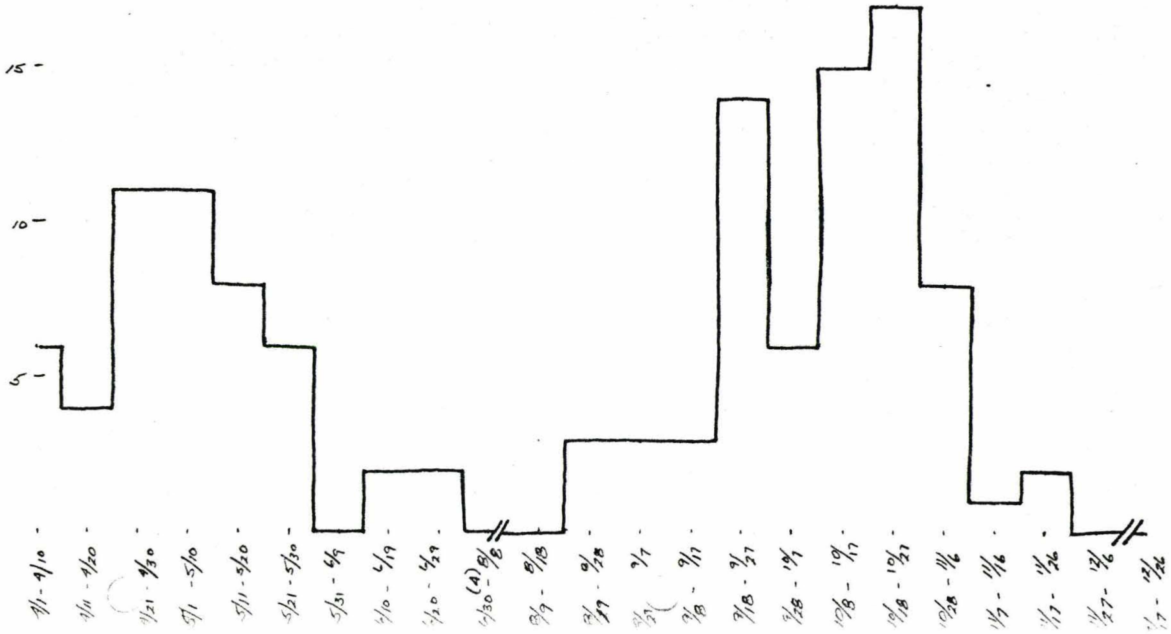
TEPEE E-14

BI 0-25
TEMP 40-65
RH 15-40
WS 5-15
1 HR FM 5-15
10 HR FM 10-15

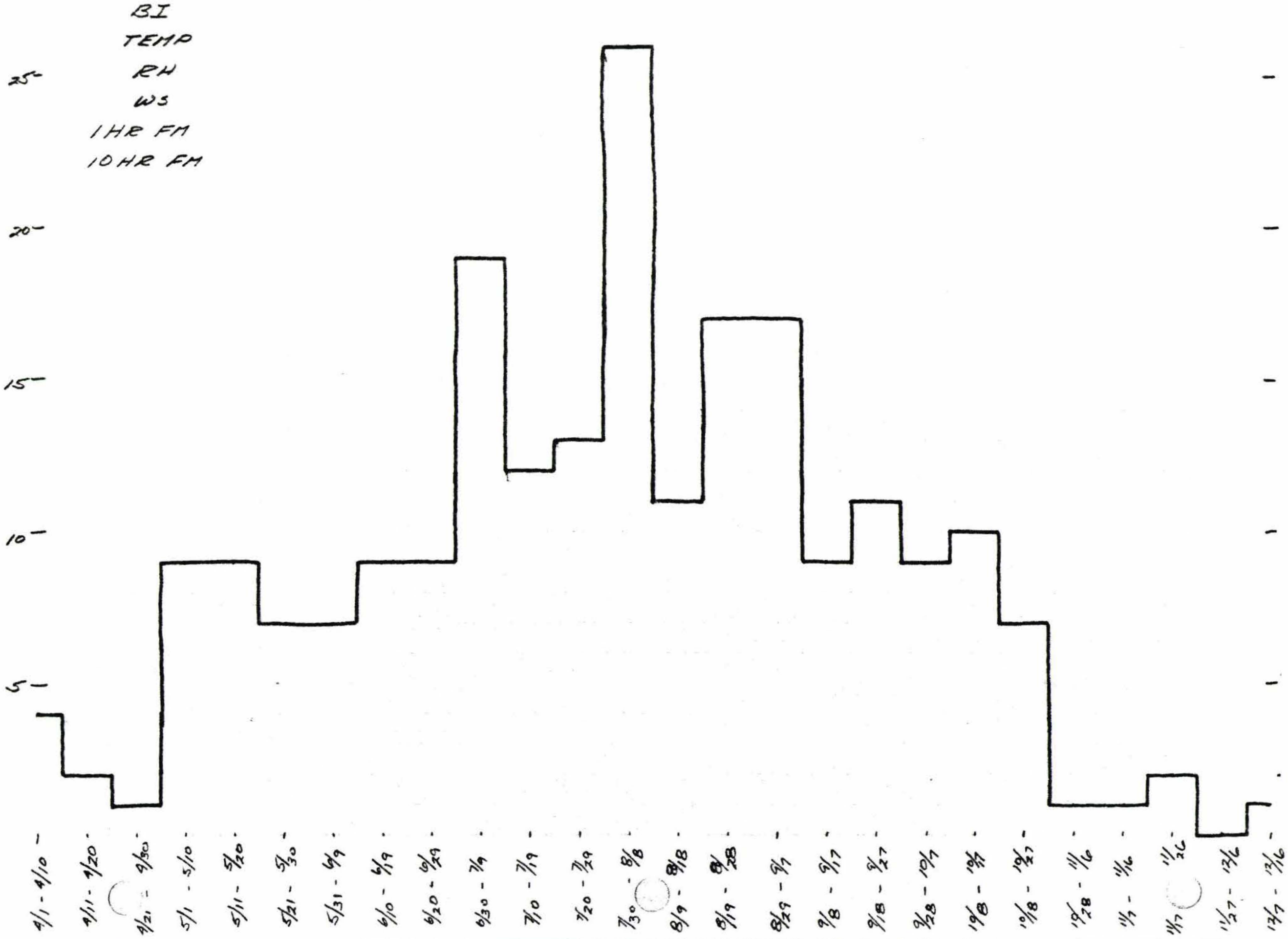


TEPEE E-13

BI 0-25
TEMP 40-65
RH 15-40
WS 5-15
1 HR FM 5-15
10 HR FM 5-20



HOT SPRINGS E-6



HOT SPRINGS E-1 TO E-5

BI 0-25
TEMP 70-90
RH 20-30
WS 3-8
1HR FM 15-25
10 HR FM 15-20

E-2
TEMP 60-90

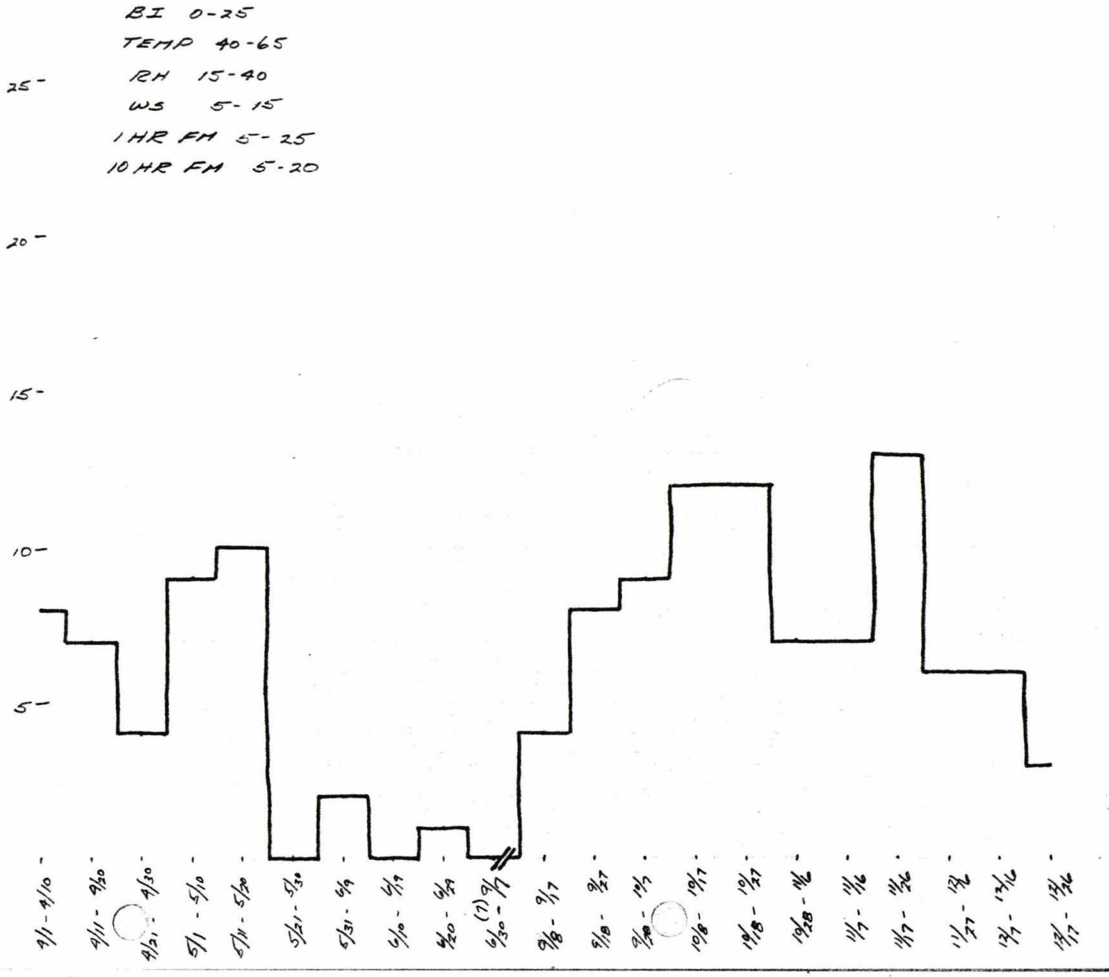
E-3
1HR FM 10-30

E-4
RH 15-40

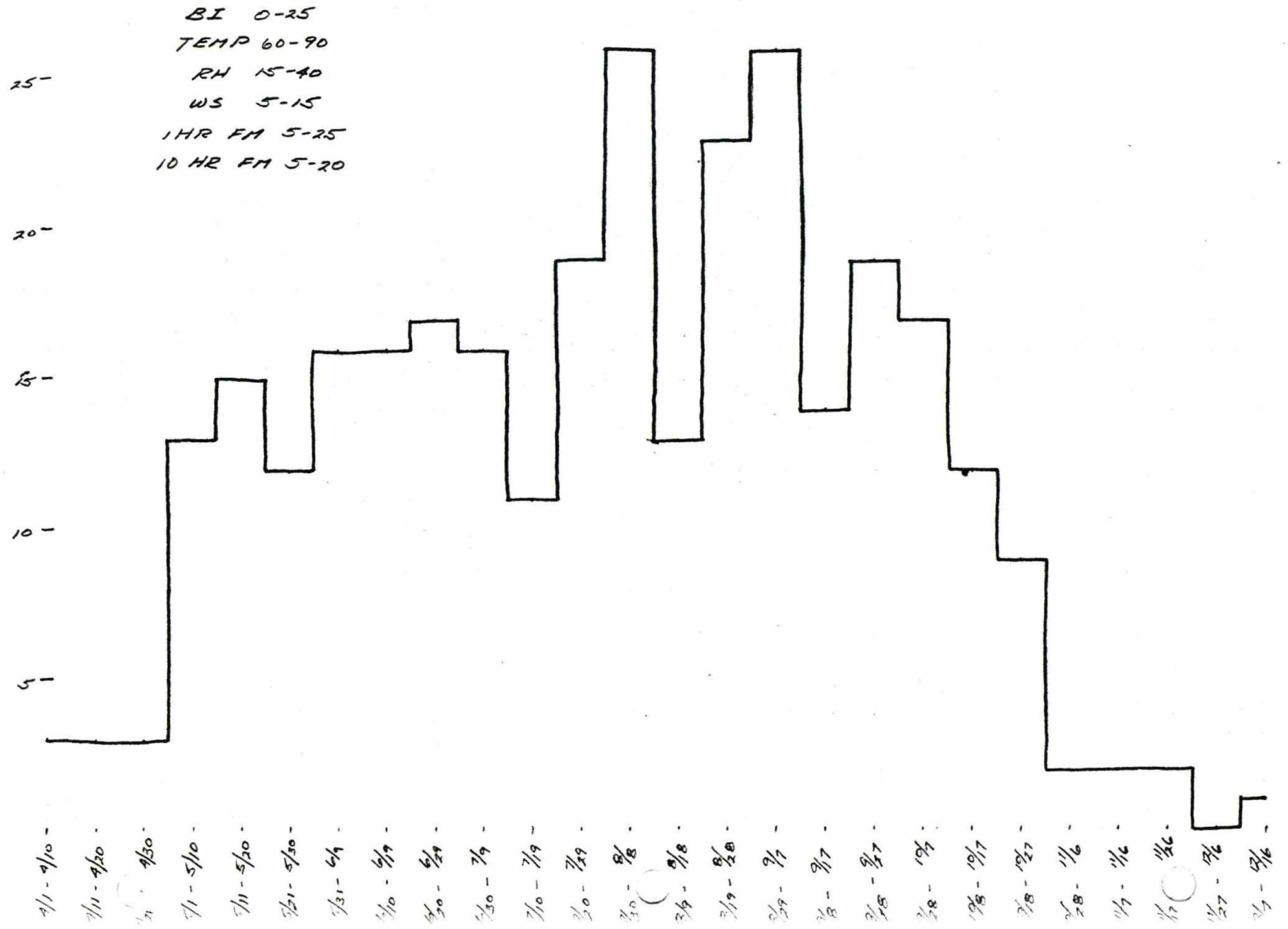
E-5
1HR FM 5-25

NO DAYS

HOT SPRINGS E-8

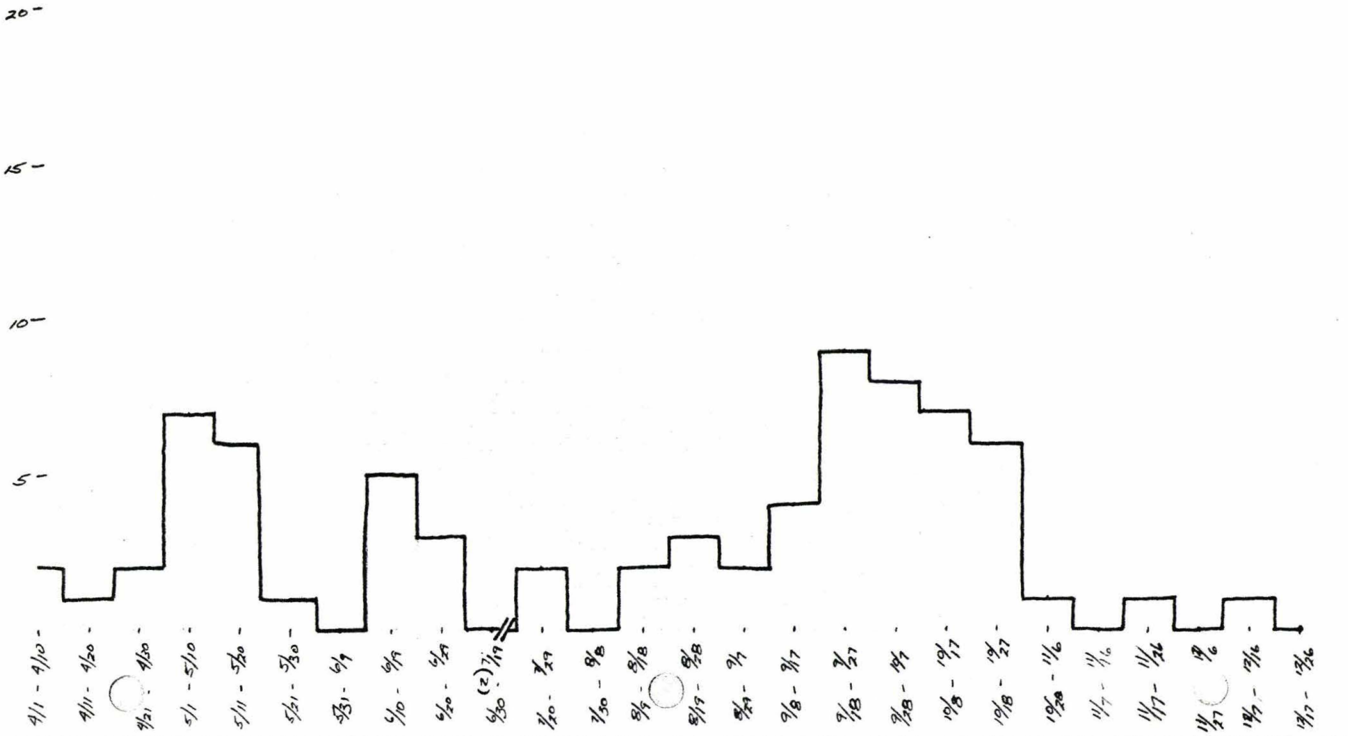


HOT SPRINGS E-7



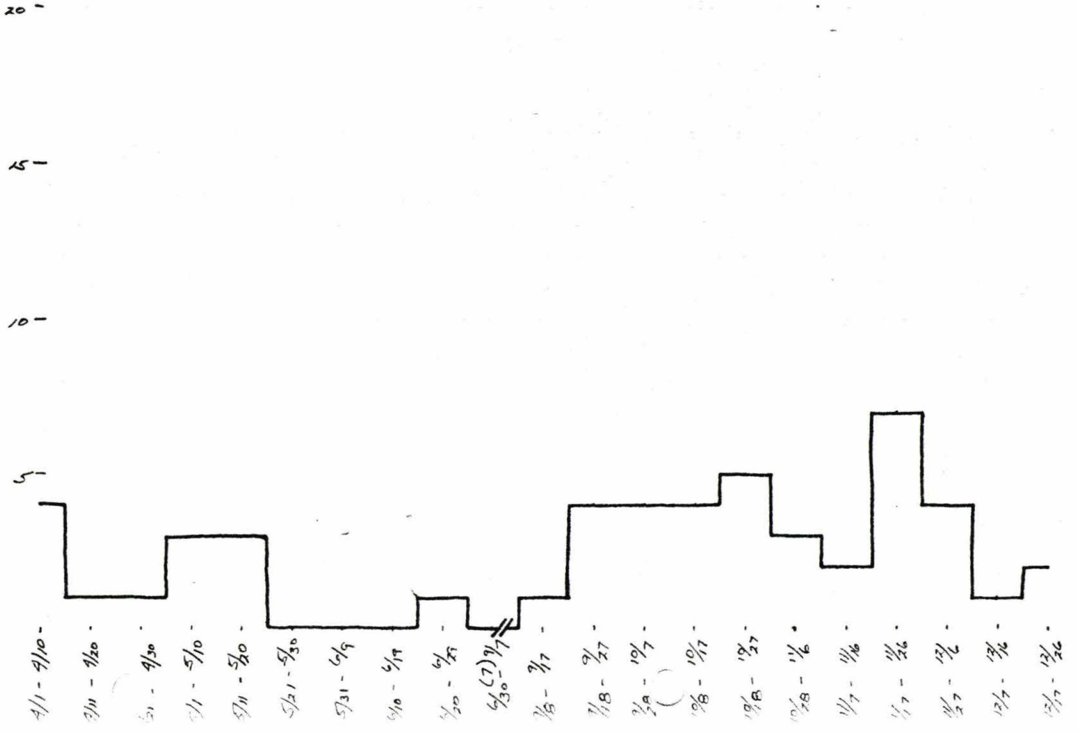
Hot Springs E-10

BI 0-25
TEMP 60-80
RH 20-30
WS 5-15
1HR FM 5-25
10HR FM 5-20



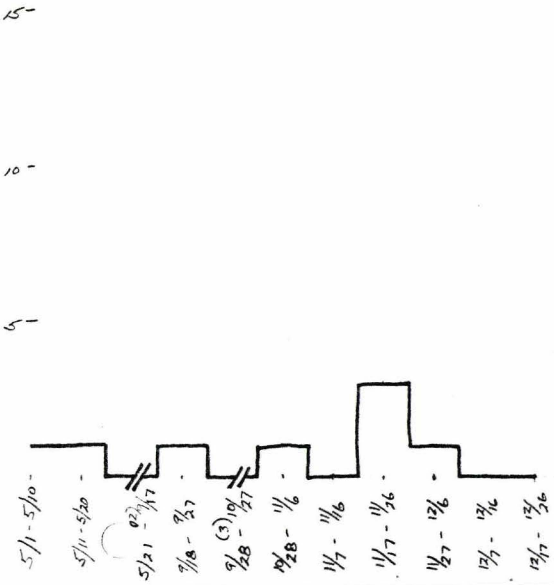
Hot Springs E-9

BI 0-25
TEMP 40-65
RH 20-30
WS 5-15
1HR FM 5-25
10HR FM 5-20



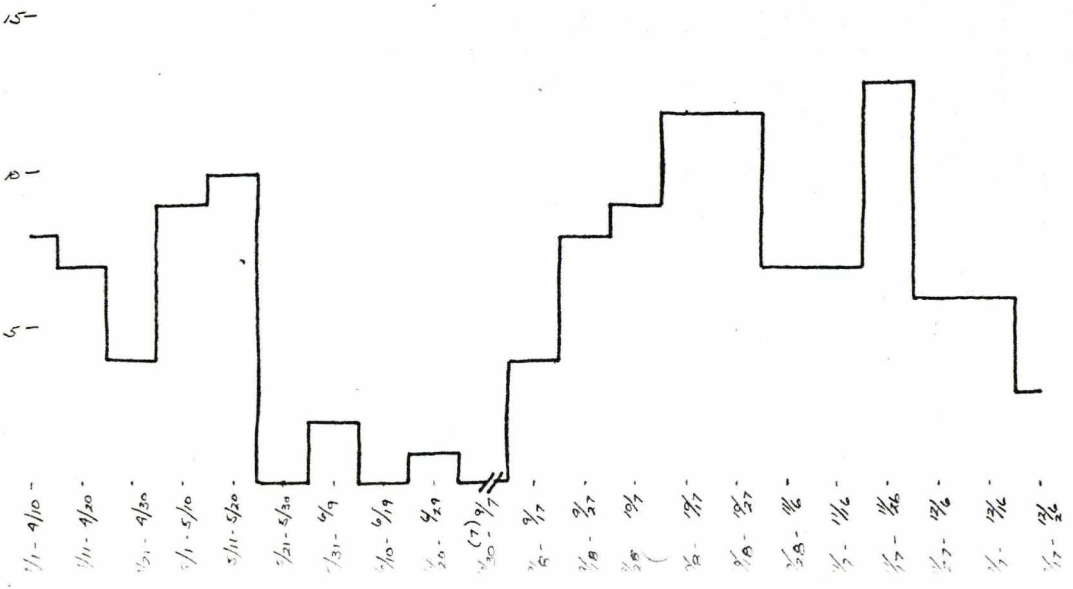
HOT SPRINGS E-12

BI
TEMP
RH
WS
1 HR FM
10 HR FM



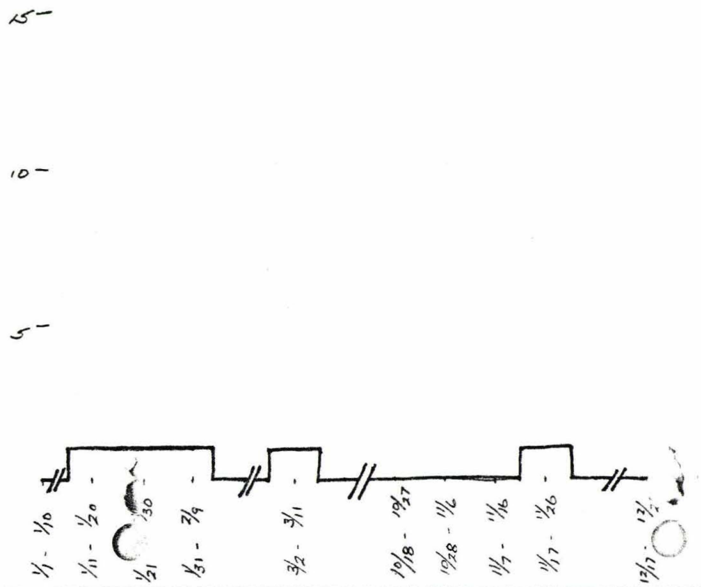
HOT SPRINGS E-11

BI 0-25
TEMP 40-65
RH 15-40
WS 5-15
1 HR FM 5-25
10 HR FM 5-15



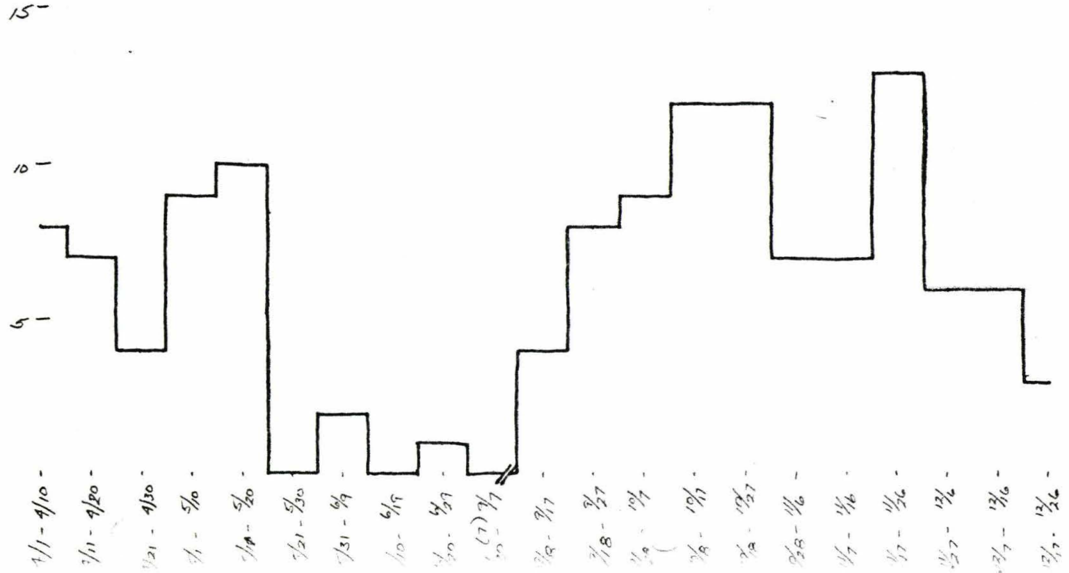
HOT SPRINGS E-14

BI 0-25
TEMP 40-65
RH 15-40
WS 5-15
1HR FM 5-15
10 HR FM 10-15



HOT SPRINGS E-13

BI 0-25
TEMP 40-65
RH 15-40
WS 5-15
1 HR FM 5-15
10 HR FM 5-20



Appendix D

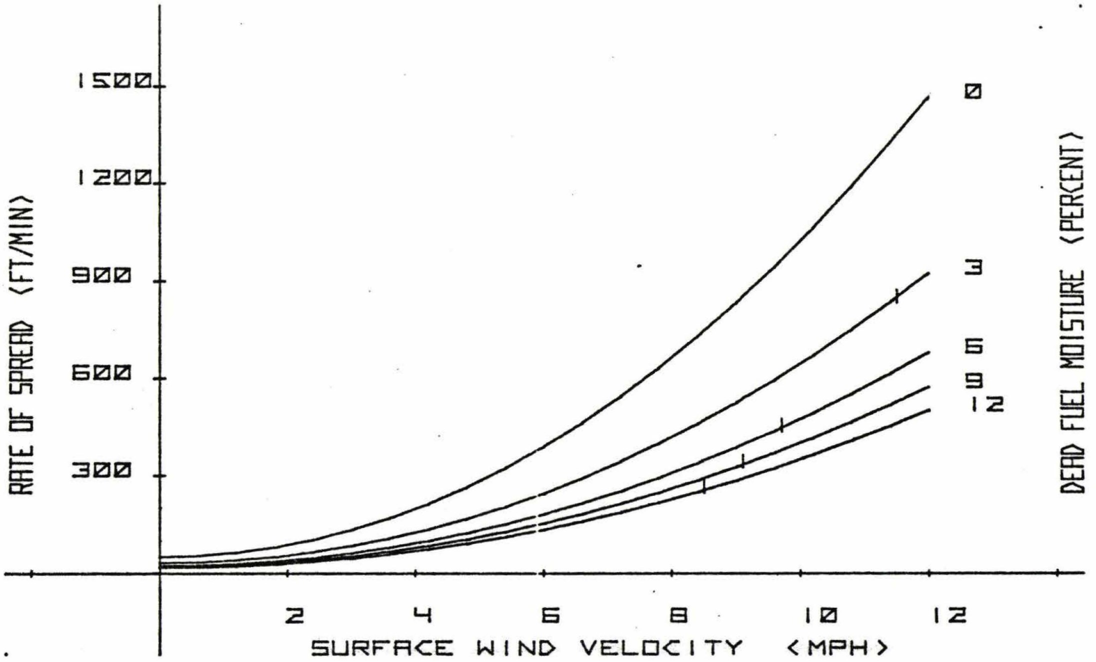
Fire behavior graphs are given for each prescription listed in the tables in Chapter 5. There are 3 graphs for each prescription; rate of spread, reaction intensity, and flame length.

Rate of spread is obtained by finding the desired surface wind velocity (along x-axis), then moving up to desired fuel moisture line. From this intersection, proceed left to the y-axis to obtain rate of spread. If fuel moisture line desired is not present, then some interpolation will be necessary.

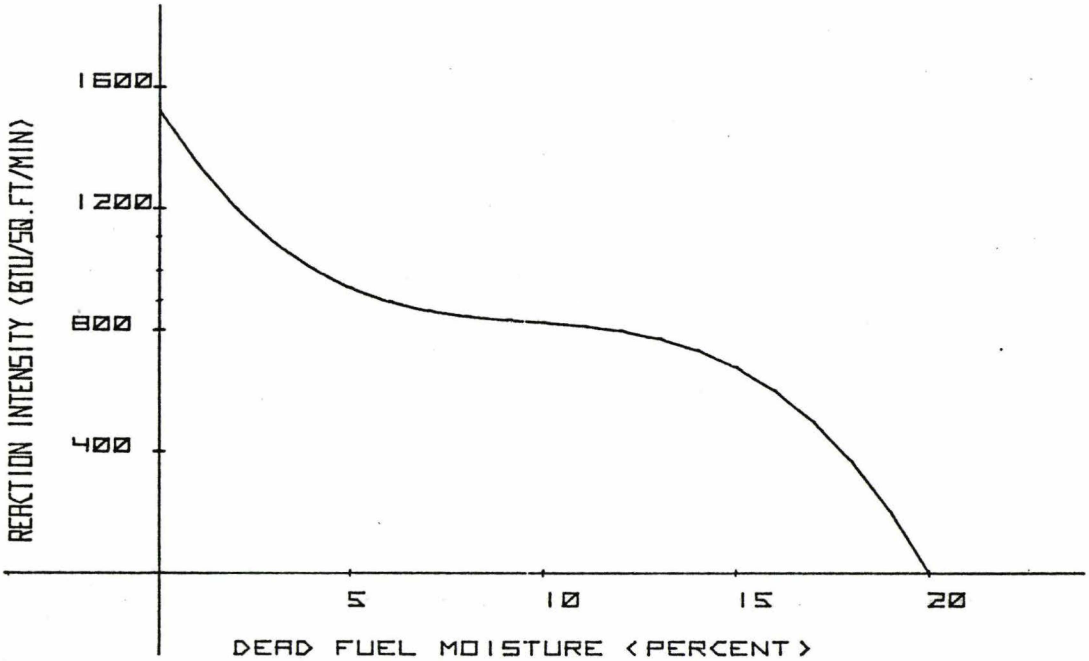
Reaction intensity if found in a similar manner. Taking the dead fuel moisture used to find rate of spread, proceed up to curve in graph, than over to y-axis to obtain the reaction intensity of the fire.

Flame length is obtained by proceeding to right from y-axis, using rate of spread value obtained from rate of spread graph, and up from x-axis using value for reaction intensity. The intersection of the two lines will give the flame length. Usually some interpolation will be necessary to find flame length.

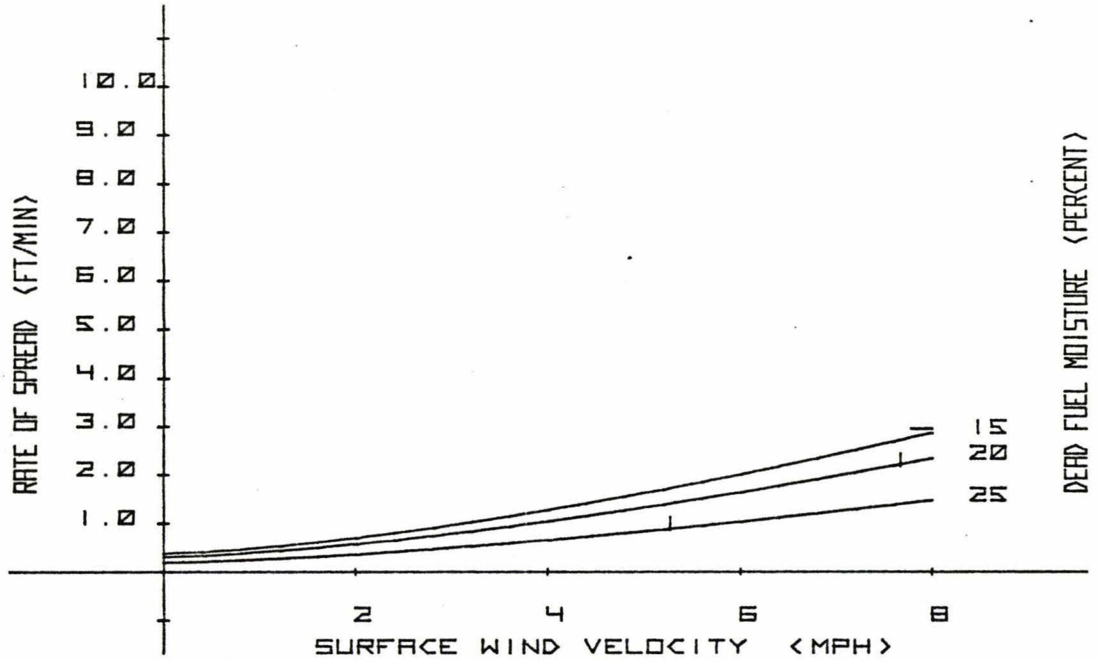
FUEL. MODEL A-1



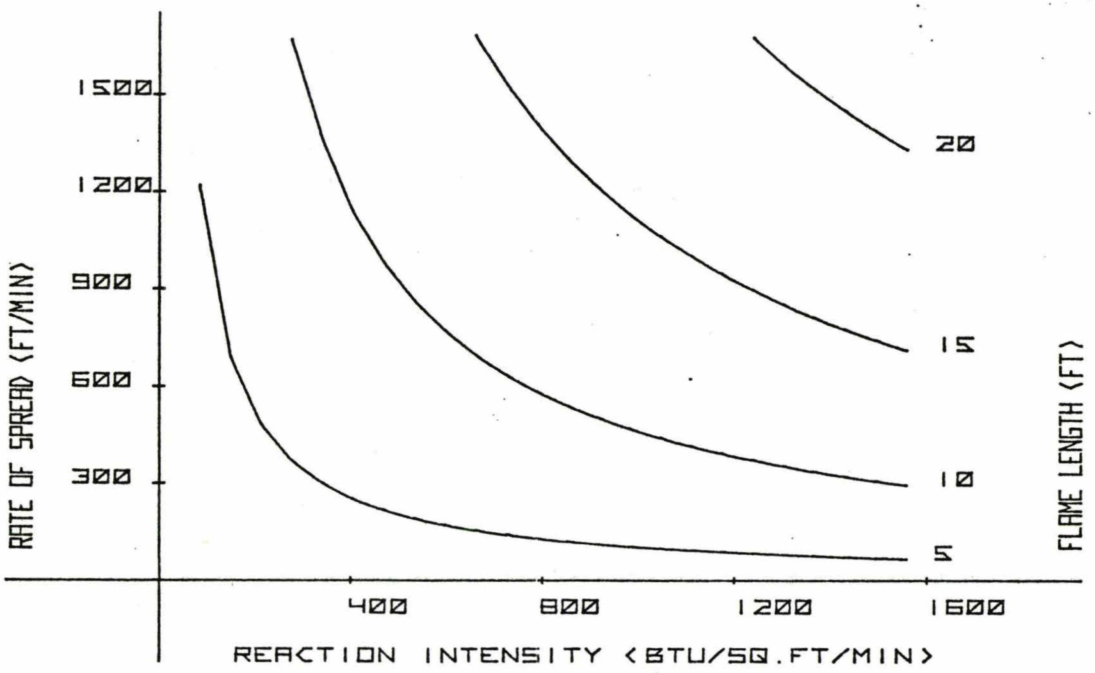
FUEL MODEL A-1



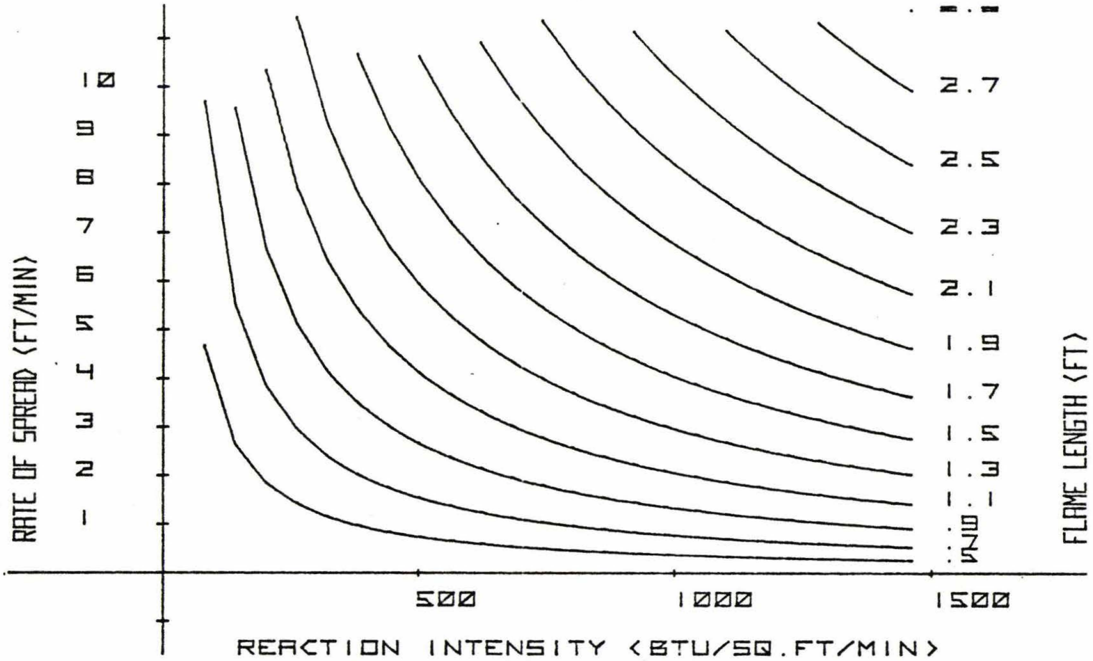
FUEL MODEL E-1



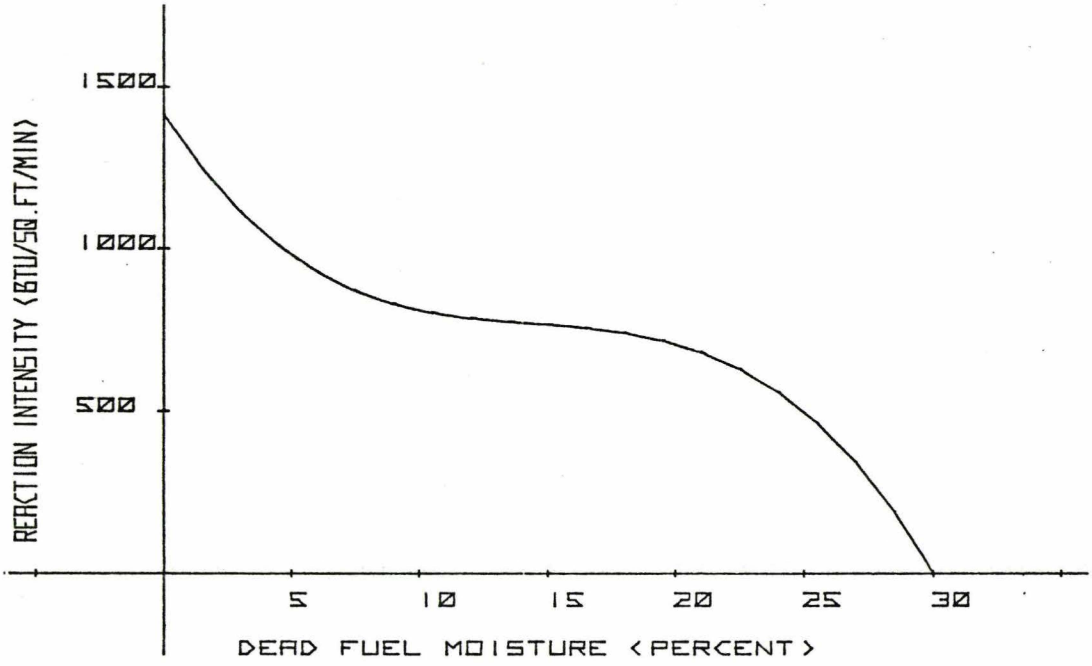
FUEL.MODEL A-1



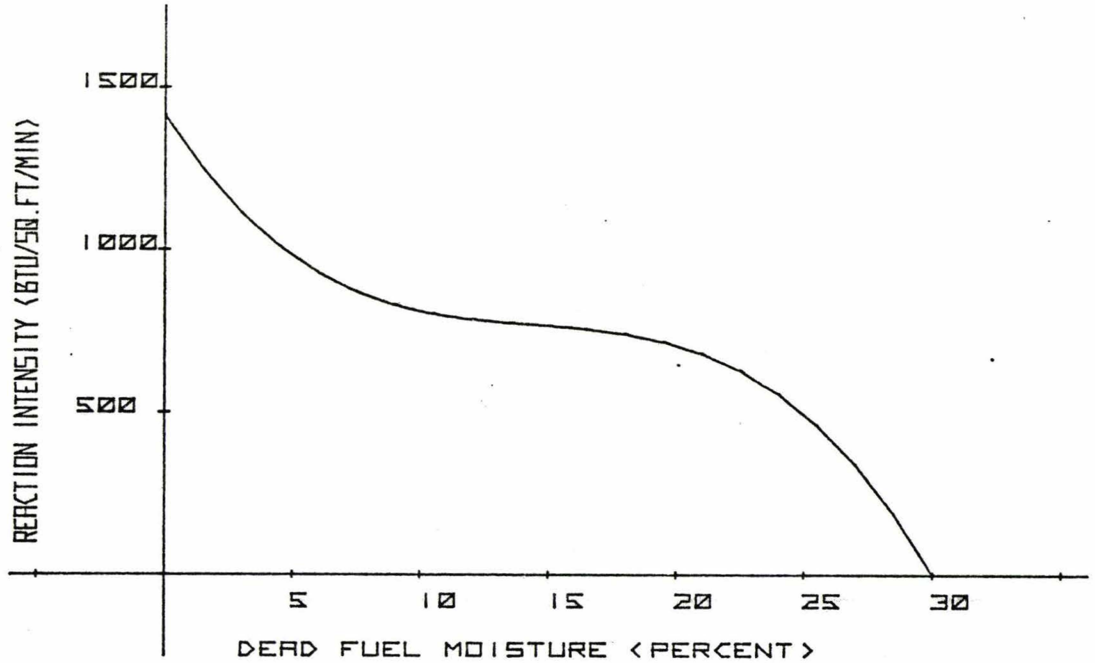
FUEL MODEL E-1



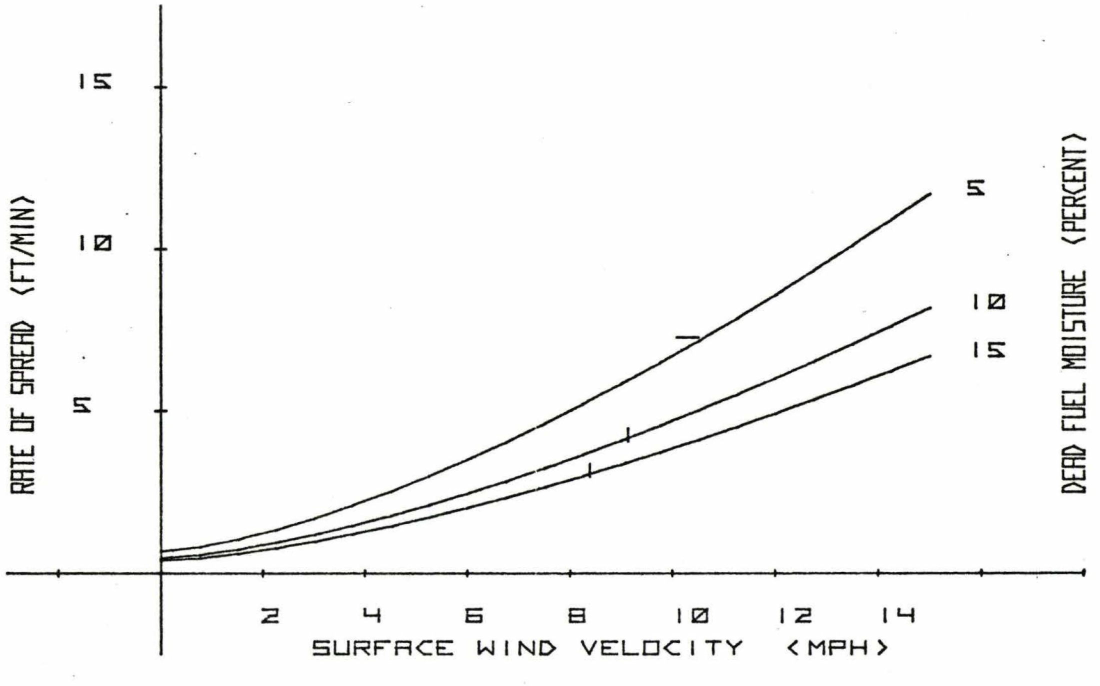
FUEL MODEL E-1



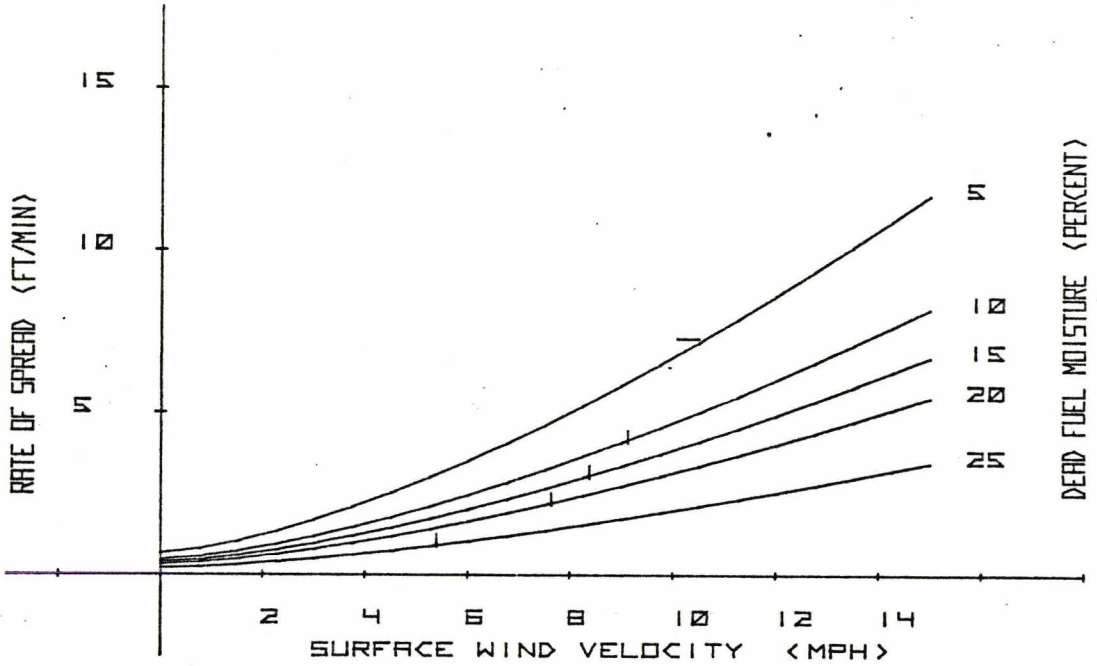
FUEL MODEL E-II



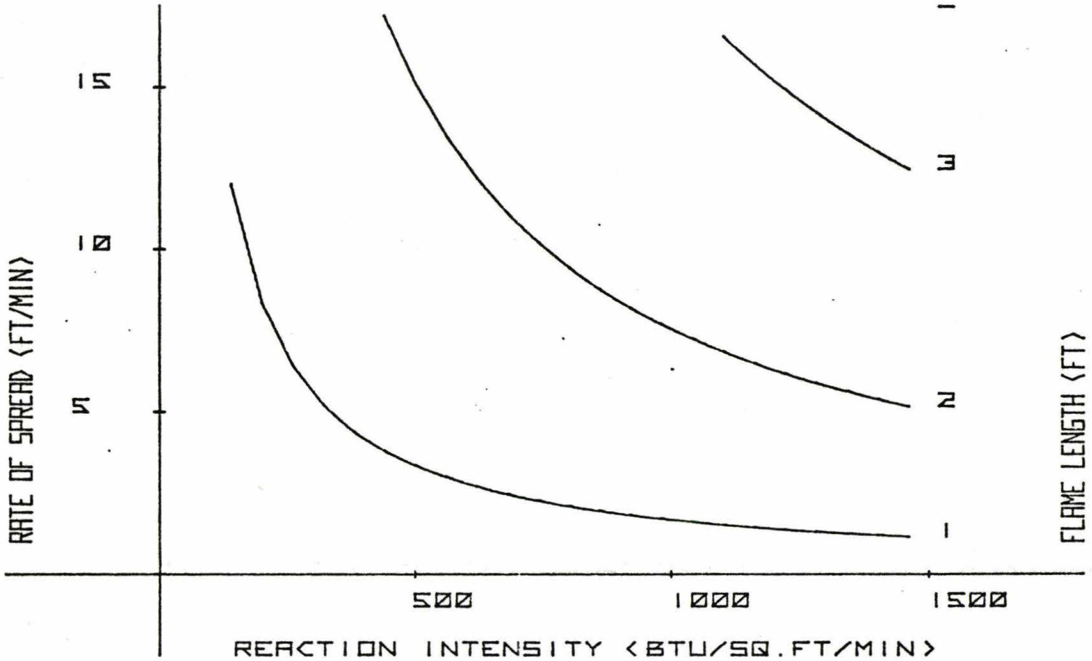
FUEL MODEL E-II



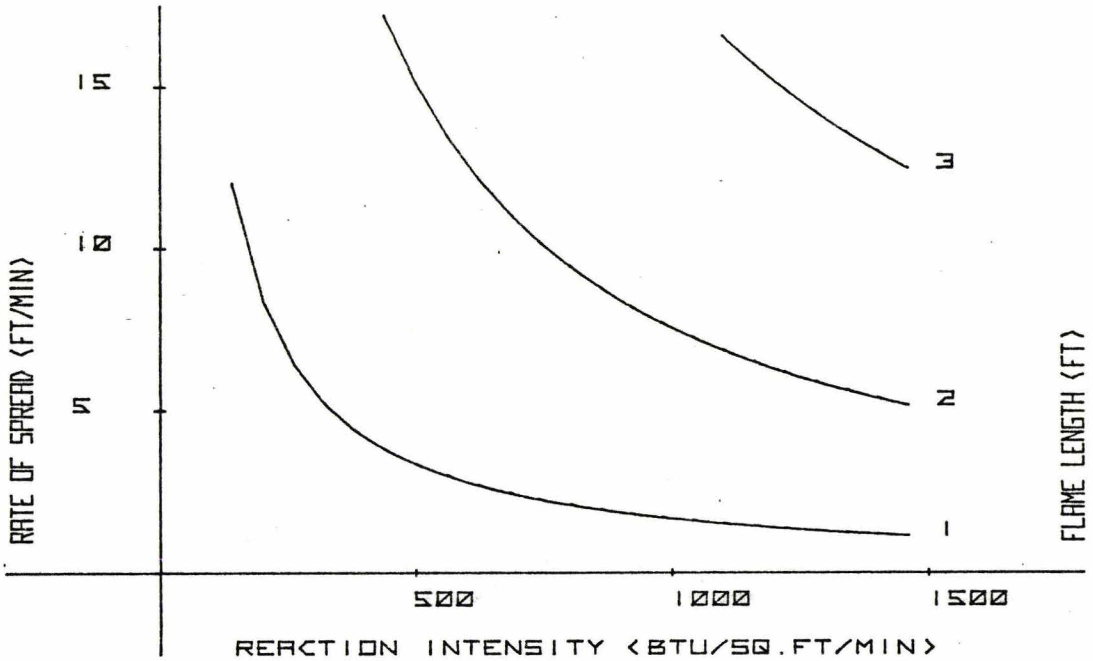
FUEL MODEL E-7



FUEL MODEL E-II



FUEL MODEL E-7



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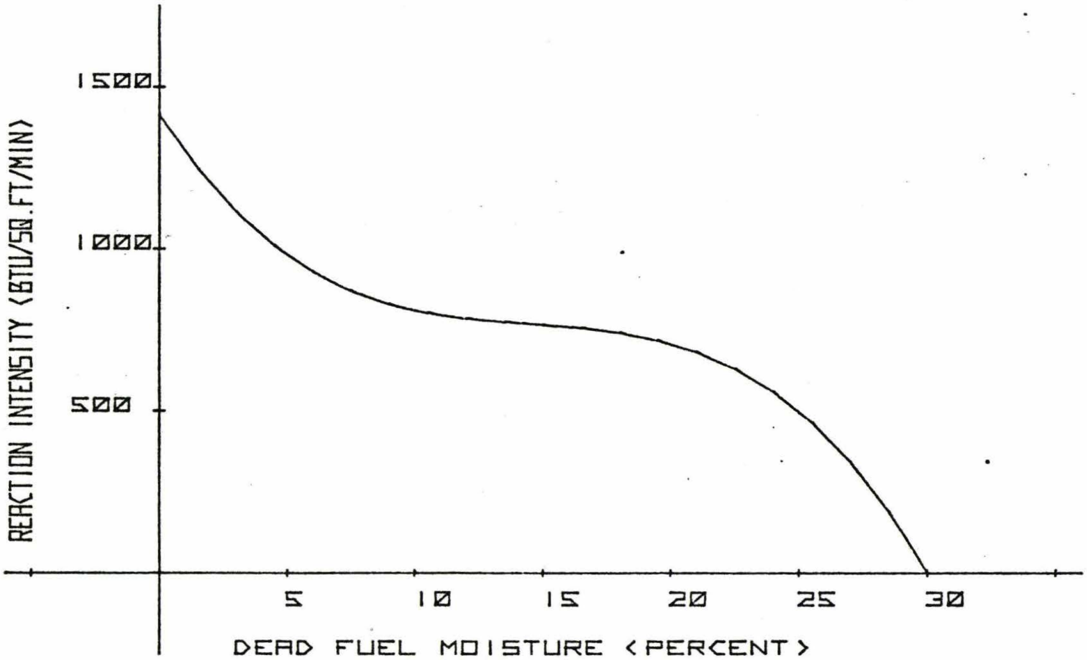
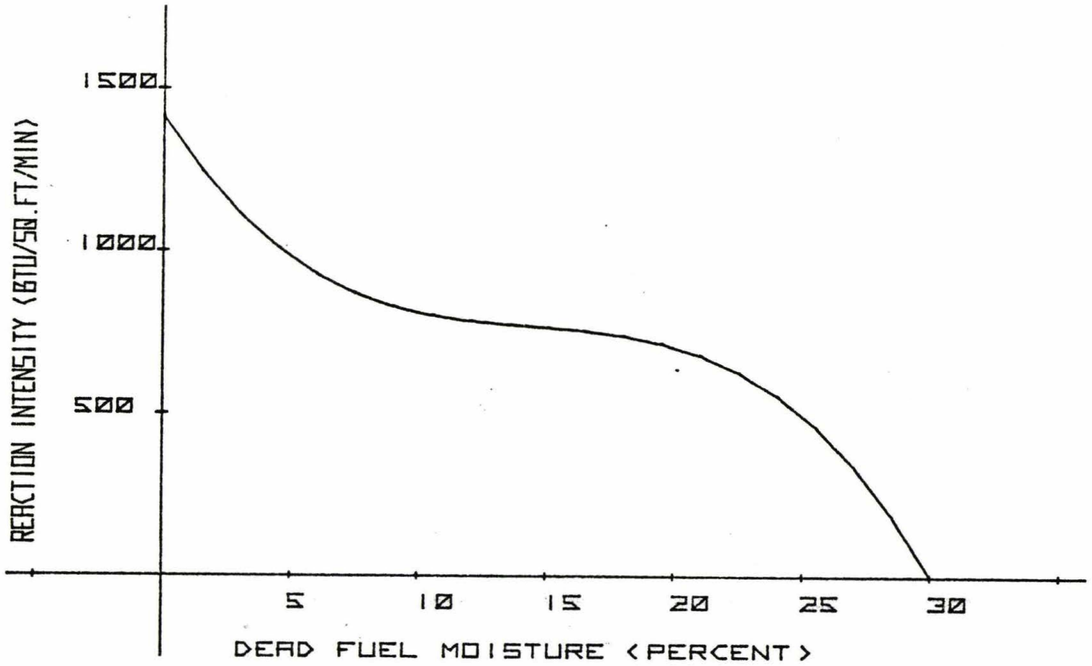
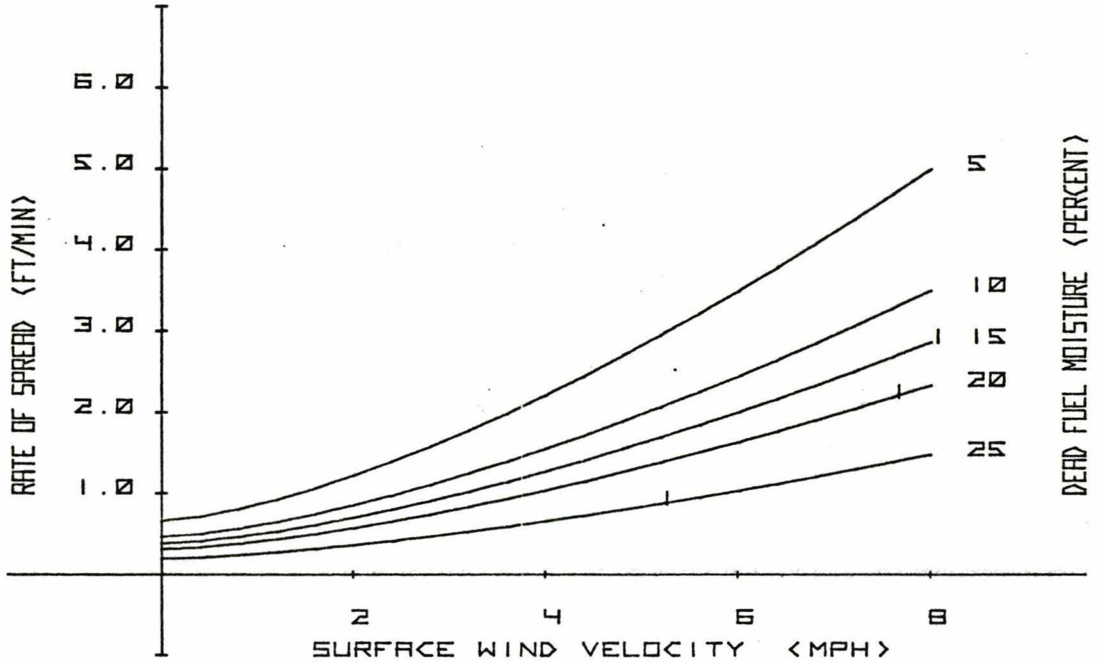


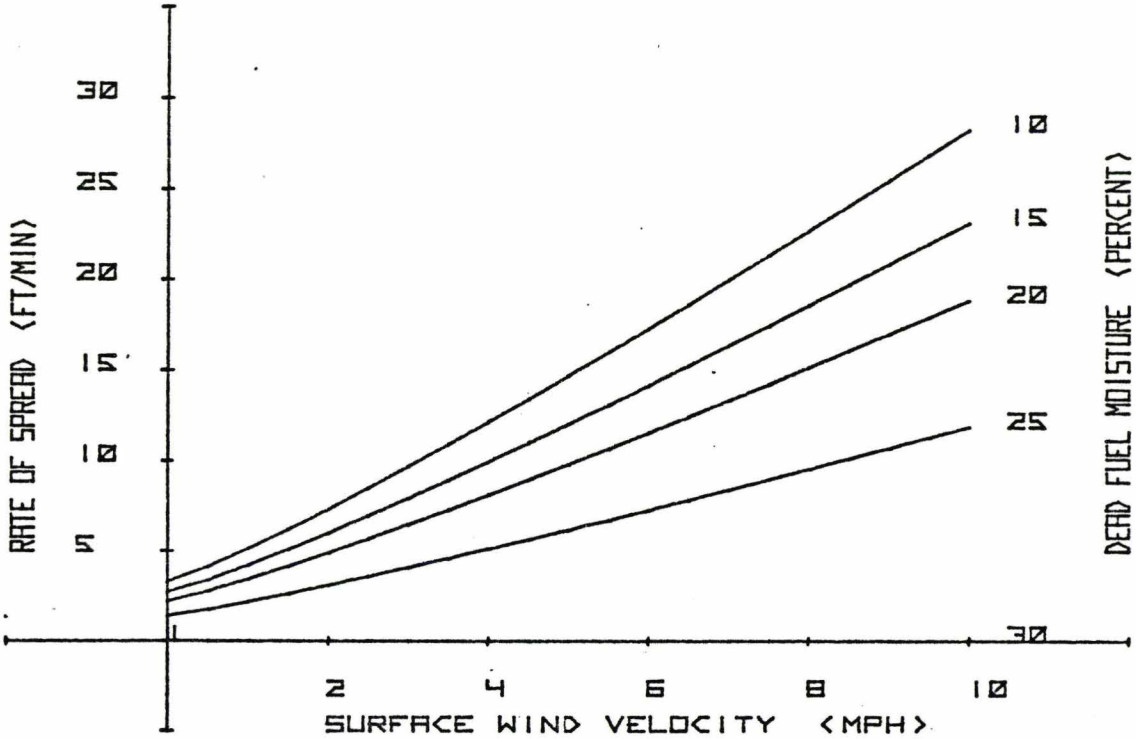
FUEL MODEL E-6



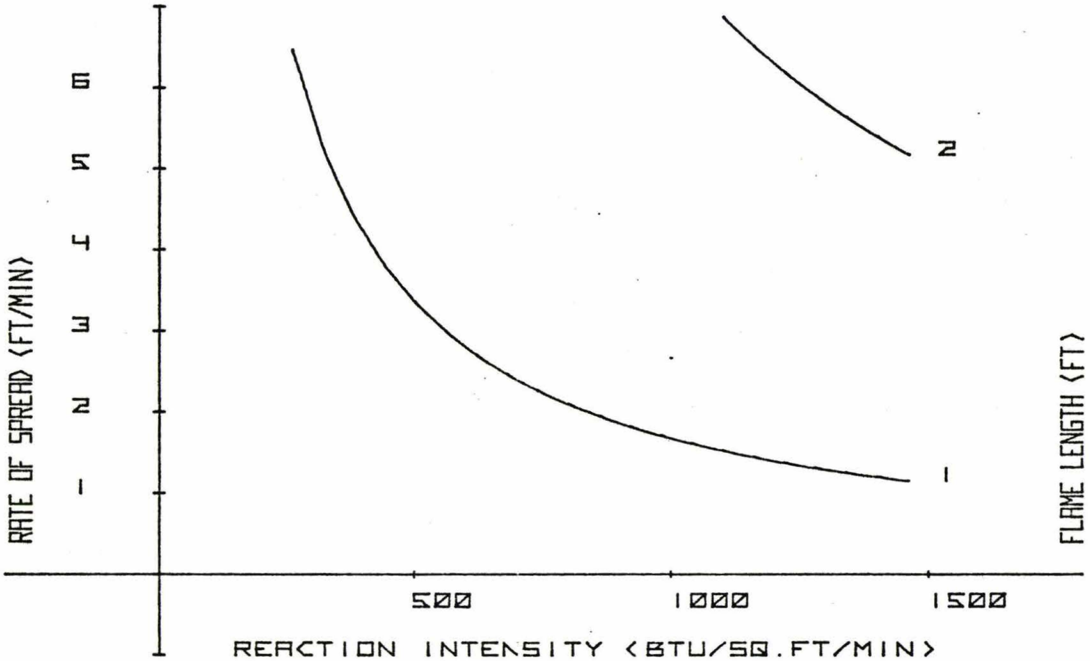
FUEL MODEL E-6



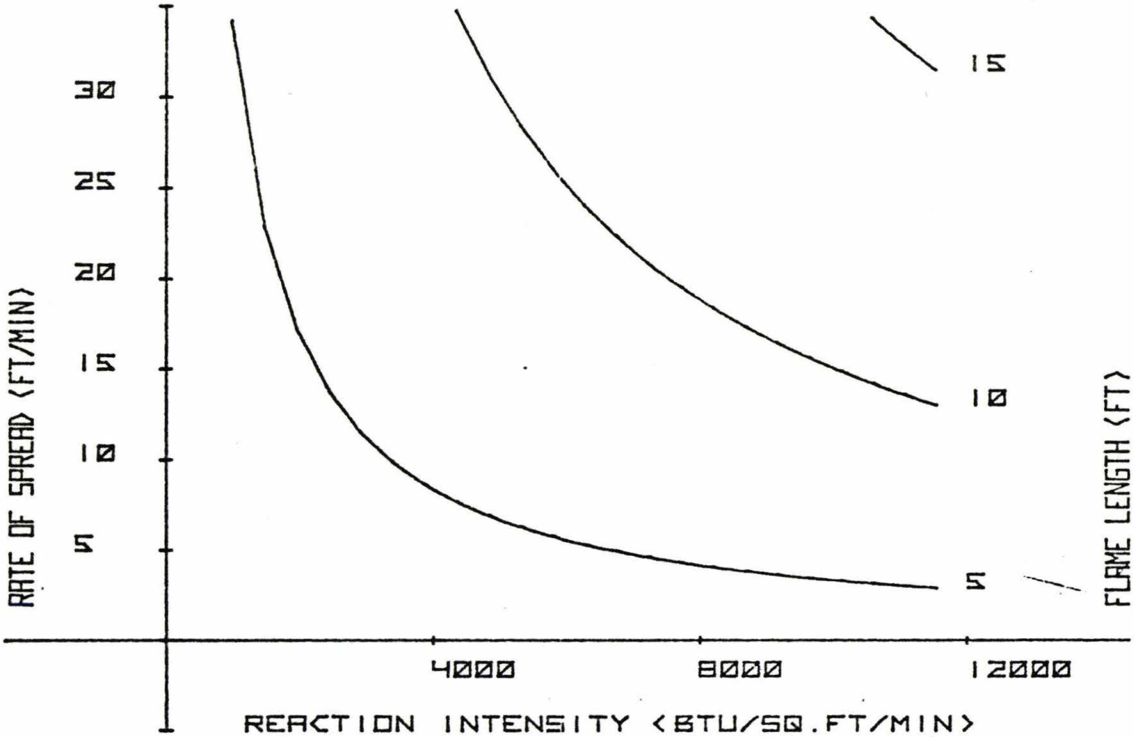
FUEL MODEL C-1



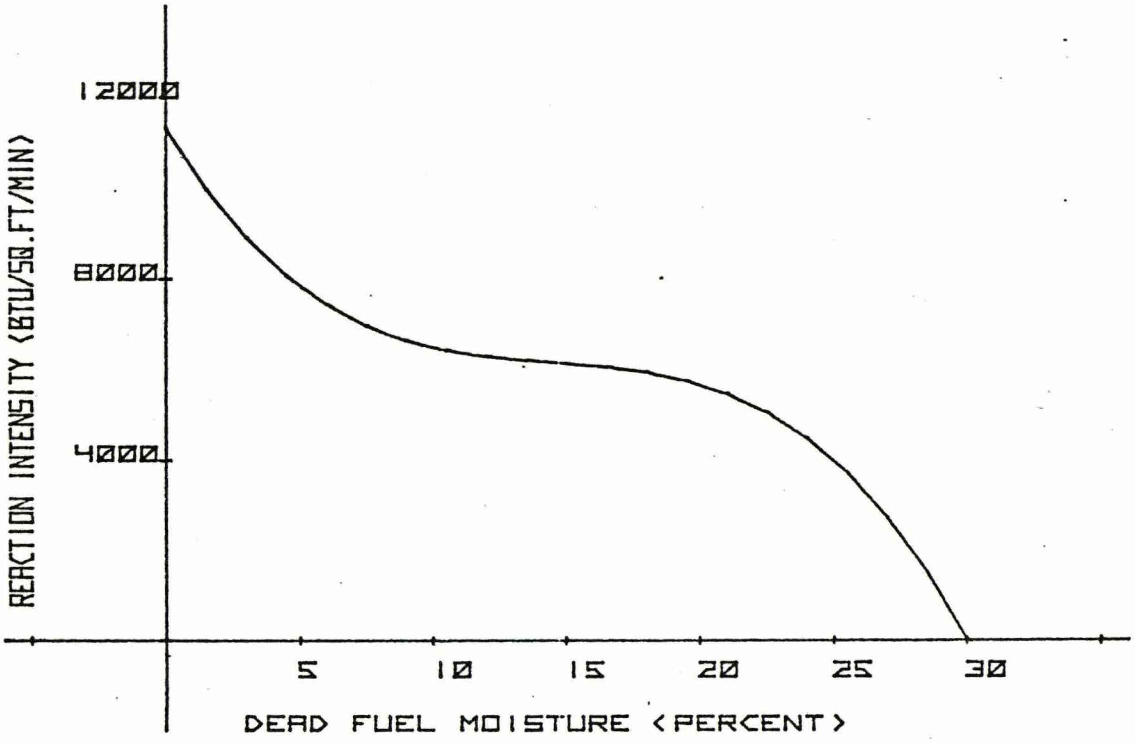
FUEL MODEL E-6



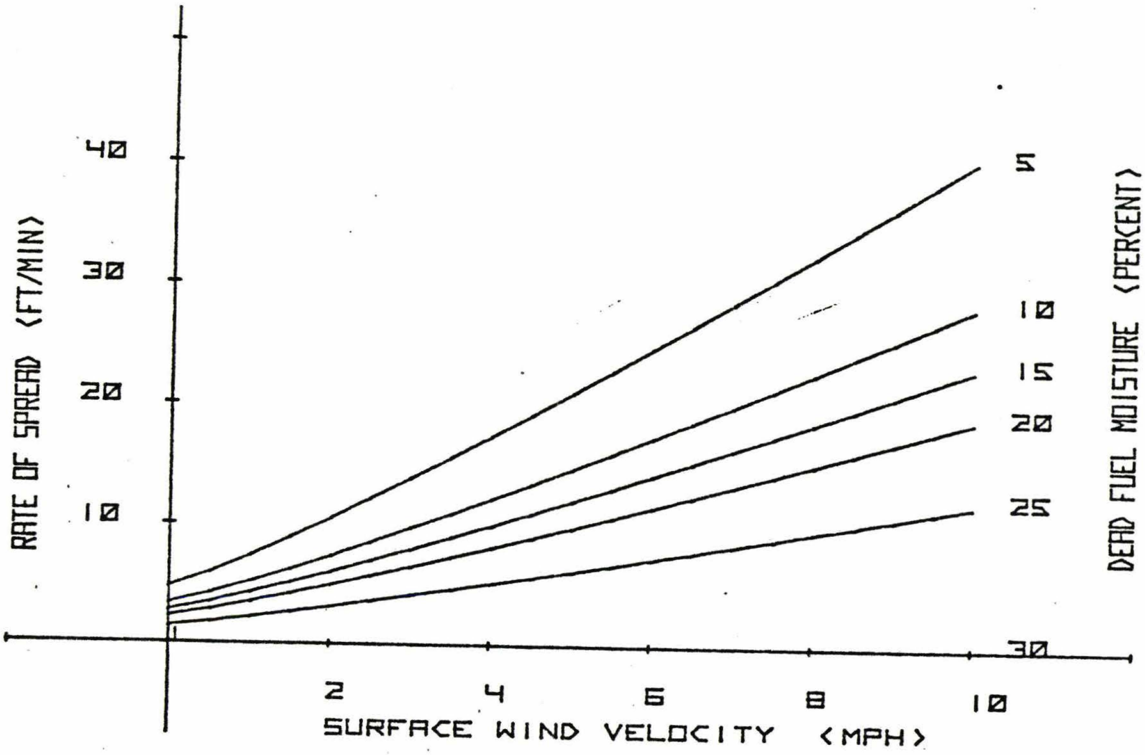
FUEL MODEL C-1



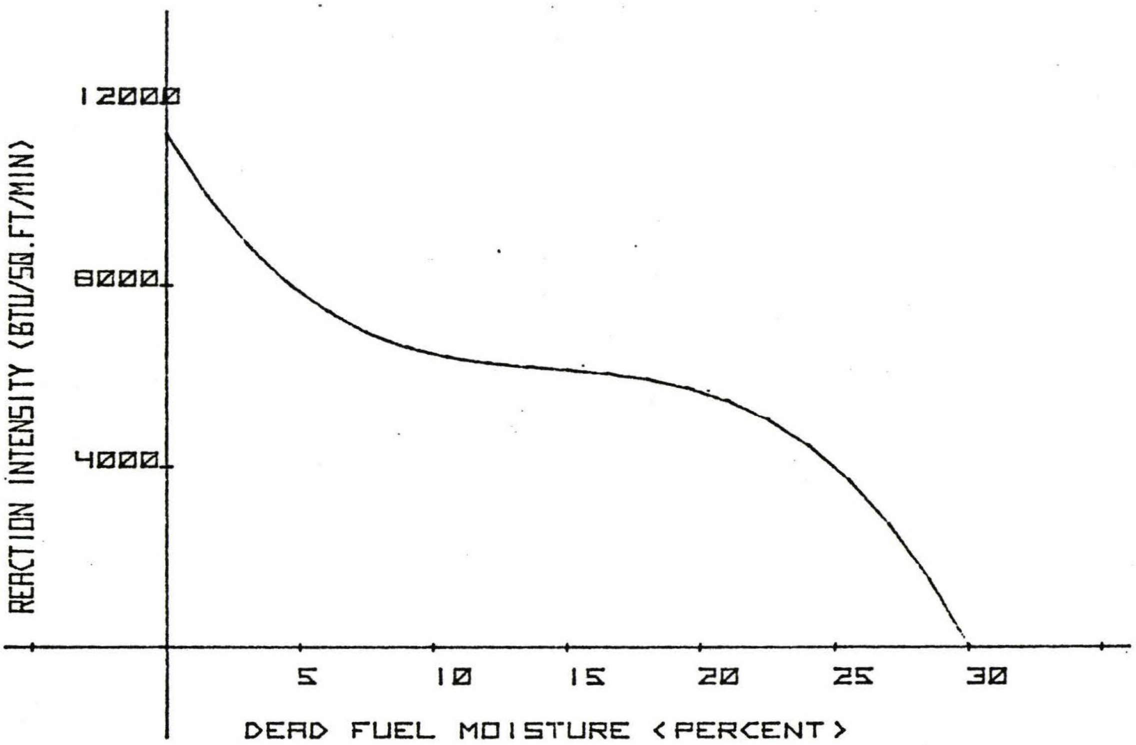
FUEL MODEL C-1



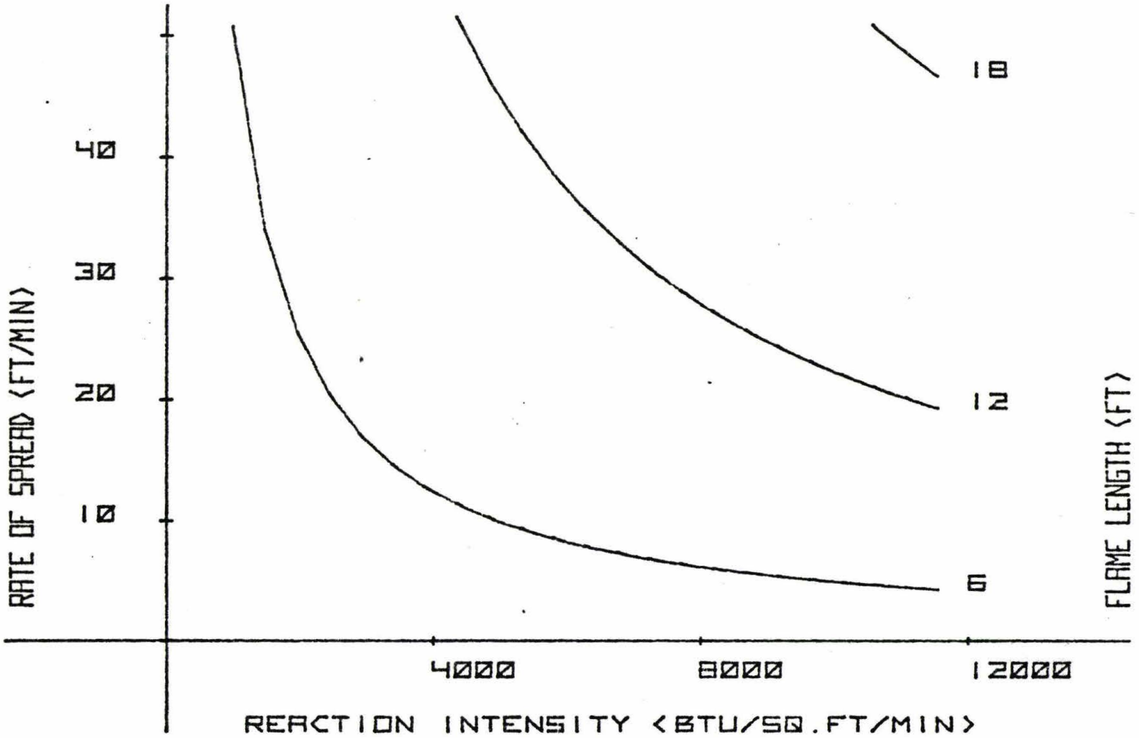
FUEL MODEL C-3



FUEL MODEL C-3



FUEL MODEL C-3



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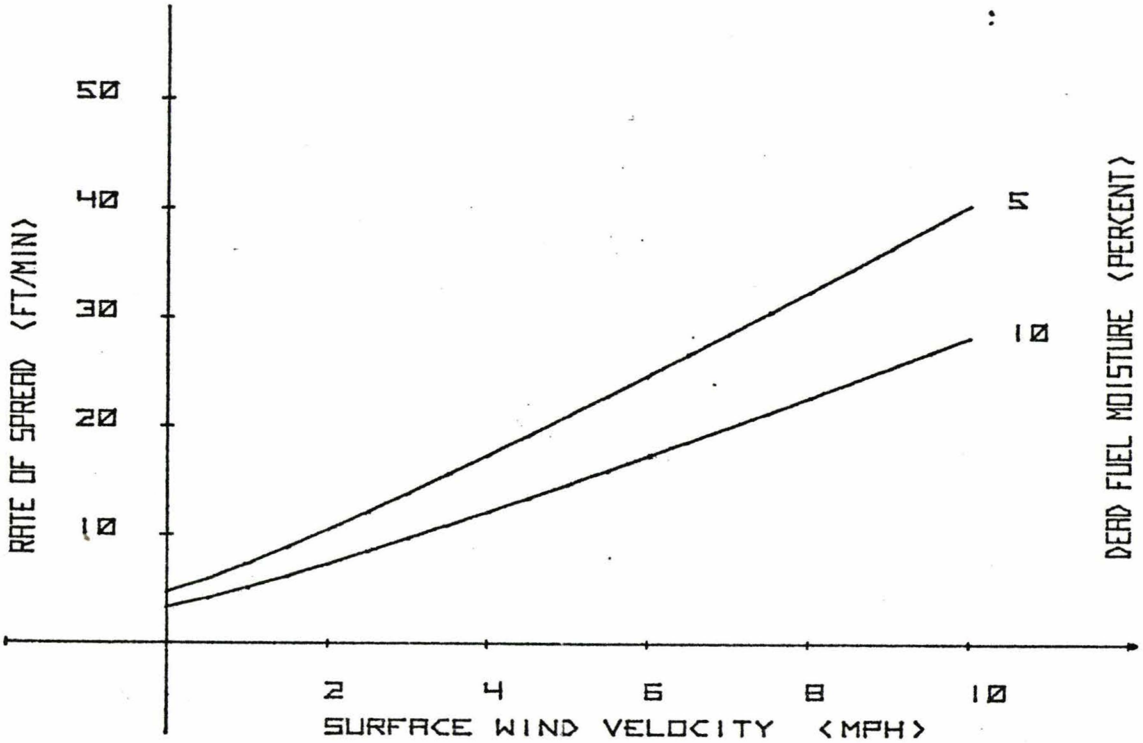

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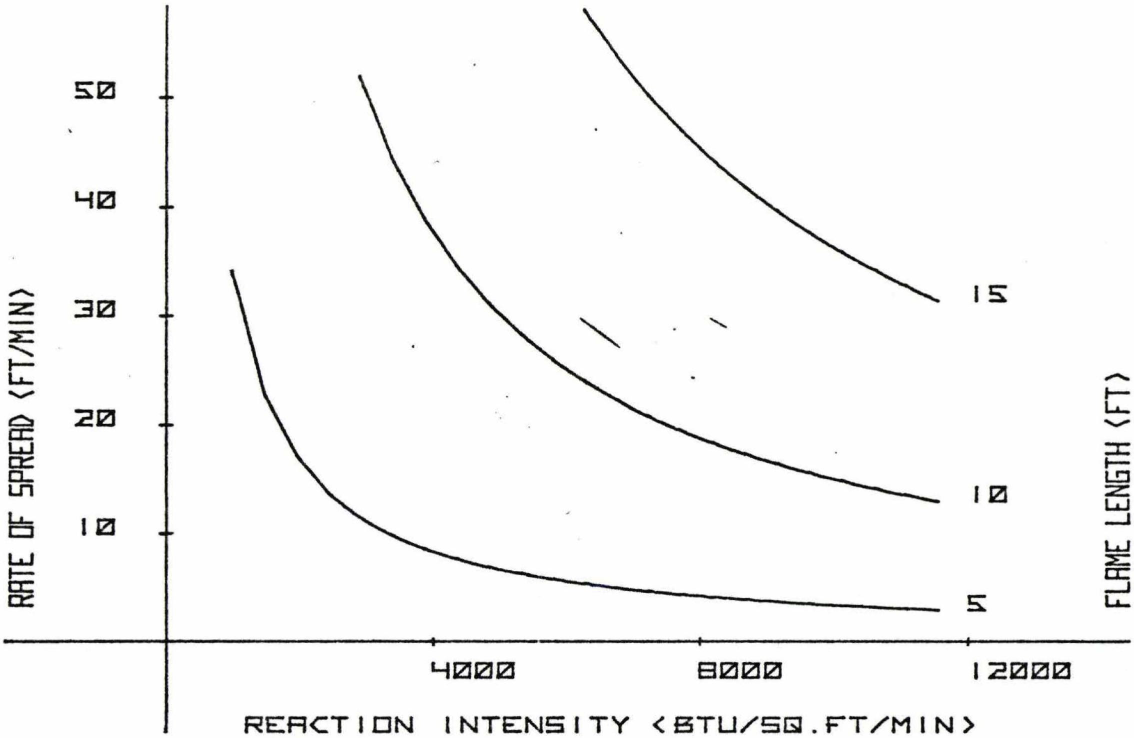

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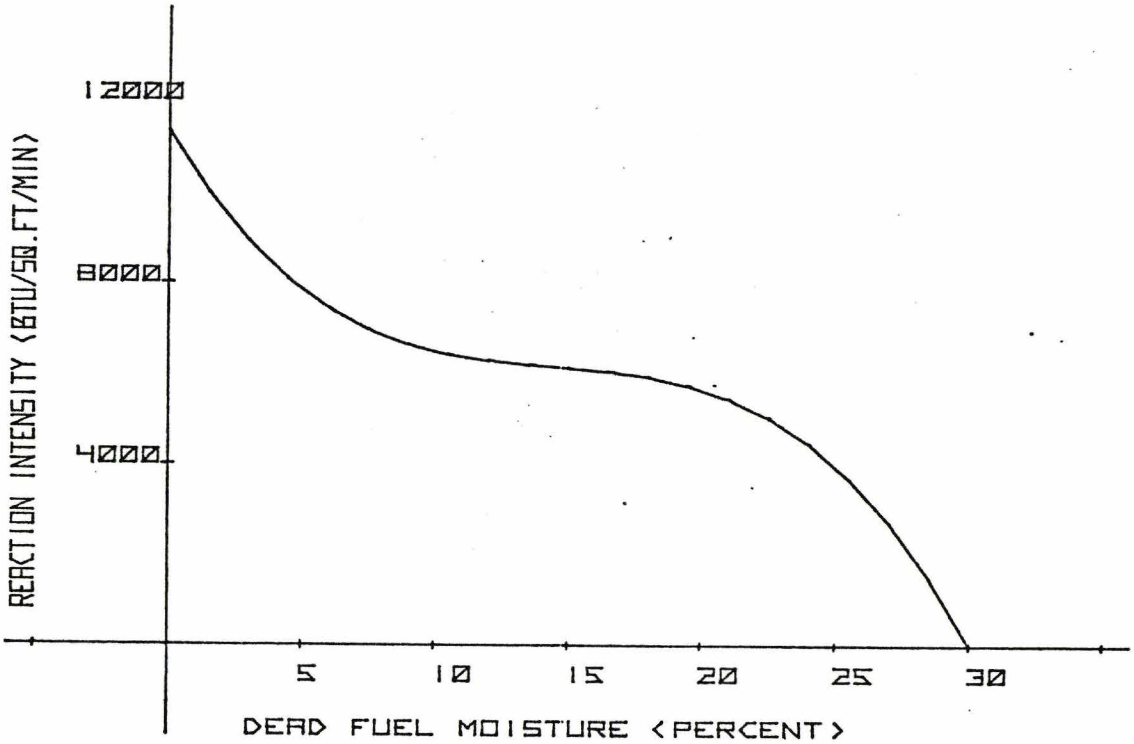

Appendix E

Report written by Bob Steele, December, 1974, as a preliminary part of this research report.

Eisenhower Consortium

report

Western Environmental Forestry Research

C.S.U. Project No. 31 - 1470 - 2093

"Possible Prescriptions for Prescribed Fire in Several Fuel Types of the Black Hills"

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VIII. References

I. Purpose

The purpose of this portion of the overall report dealing with promoting use of fire in the Black Hills is: --

1. to describe the fuel types present that are candidates for prescribed buring treatment, and

2. to describe the weather and fuel conditions thought necessary for successful burning in the various fuel types.

The testing of this prescription and the probability of the occurrence of these weather conditions will be reported on by another investigator.

The background describing past fires, earlier prescribed burning, and the need for future fire management is well discussed in the study plan for this project and will not be repeated here. The study plan is titled -- "Frequency of Satisfactory Conditions for Prescribed Burning in Ponderosa Pine Forests of the Black Hills."

II. General Description of the Timber Stands

Ponderosa pine is the dominant species that fire is involved with. The pine stands in the Black Hills cover about 14 million acres of land and vary from overstocked pole stands containing 5800 stems per acre where growth is stagnant to open, park-like stands with large, widely spaced trees with grass as an understory (Alexander, 1974). There are also parks or openings where the pine has not competed successfully with the grass. Logging has occurred for many decades and much of the area shows the diversity of age classes that follows selective cutting.

Intensive timber management and fire suppression since the first settlement in the 1870's has drastically altered the ecology of the pine forests, creating denser stands of pine seedlings and poles that are less desirable for timber production, forage and browse production, and fire control. Settlement has also created a patchwork pattern of land ownership with recreational sites, residences, and ranches scattered throughout the forested area. This ownership pattern makes it difficult to achieve optimum fuel management, whether by fire or other means.

On lands other than State owned, 76% of the pine is suitable for veneer logs, 21% for saw logs, and 3% for stud logs (Yerkes, 1974). These figures indicate the huge potential of this area for the production of forest products. The wise forest manager will take advantage of this timber growing ability for the Black Hills and attempt all the management practices that enhance pine timber growth. Among these practices are pre-commercial thinning, commercial thinning, sanitation and salvage logging, selective cutting, and some clear cutting. Common to all these practices is good fire management (Weaver, 1967).

III. Fire History

Historically, there has always been a zone of tension between forest and grassland. Woody and herbaceous vegetation have competed with each other on most every continent. Their struggle for light, water, and nutrients has at times and on certain sites favored one kind of vegetation over the other because of differences in climate, soil, and topography. In most cases where the actions of man have directly or indirectly caused herbaceous vegetation to regress by overgrazing or by near total exclusion of natural fires, woody plants have increased and, in many cases, become dominant. Explorers of the Black Hills alluded to the role of fire in maintaining open grassland along with the ponderosa pine forest. Fire was also a contributing factor in restricting pine encroachment into foothill grasslands.

Frequent wildfires, started by intense summer lightning storms destroyed some pine stands that left openings in the forest, but at the same time, these fires were responsible for maintaining healthy pine timber stands. The role of fire has been changed somewhat by the actions of man, but certainly wildfire has not been eliminated.

Periodic large fires have occurred, and a strong prevention effort could be financed completely by the savings in cost of just one such large fire. The answer to large fire occurrence lies in fuel management; however, rather than in prevention efforts or suppression techniques.

IV. Fuel Types

The following fuel conditions in the ponderosa pine timber type of the Black Hills are identified here as being separate enough to warrant the use of fire in a little different manner one from another. The specific application of fire to these fuel types will be discussed under Part V, fire as a tool of management.

A. Overstocked stands

These are stands that developed naturally where ground was scarified or burned and an abundant seed source was available. They have developed without fire or other disturbing influence. Pine, though intolerant, does continue to live and grow in a crowded condition where up to 6000 stems per acre are possible. Dense shade keeps understory vegetation to a minimum.

The principle fuel here is composed of needles, twigs, limbs, some grass, and an occasional down log or "remnant" from a previous forest. Fuel in amounts of 4 tons per acre are possible, the dominant and co-dominant trees have reached 6 inches d.b.h. and have developed the characteristic inch or so of bark near the base.

Stand ages can be from approximately 30 to 70 years where crown closure is still complete.

These stands are considered as Fuel Type C for the National Fire Danger Rating System (Deeming, 1972).

B. Open grown stands

These stands resulted from natural thinning due to fire or from past logging operations. They contain merchantable timber today with densities ranging from 20 trees per acre up to 85. These stands are an intregal part of the forest management plan for timber harvesting because they are accessible to logging, have roads developed through them, and are on sites that are producing satisfactory growth.

The fuels are more scattered than in the overstocked stands and many consist of remnants of old logging slashings as well as grass, forbs, and brush that have developed as an understory because more light comes through the open forest canopy.

These stands are considered Fuel Type C for the National Fire Danger Rating System.

C. Selectively cut stands

This fuel type is made up of the logging slash created from selection logging. The timber harvest may be a light sanitation-salvage cut where only a few large trees are cut and a minimum of slash is present. The slash in this case will be more or less concentrated in bunches near where the tops of large trees fell. The timber harvest could also be fairly heavy where much more slash would be created, plus all the possibilities in between.

Slash in these areas is often piled by machines and sometimes by hand. The piling can consist of merely moving the tops and limbs away from standing trees, or it may be complete piling of all slash.

These stands are considered Fuel Type B for the National Fire Danger Rating System.

D. Thinning slash

The effect of thinning has been repeatedly shown and if the forest manager wants to put the growth potential of the site on fewer trees, thinning will be done. The slash resulting from thinning is seldom removed from the area, nor is it re-arranged much because of the high cost of moving it. This slash remains close to the residual trees and unless the thinning is done when the leave trees have bark thickness of an inch and a half, too much heat will result from burning and the residual trees will be killed. Most of this thinning is done when the trees are young and have not grown very thick bark.

To be effective, thinning must release the "leave trees" on at least two sides. This practice results in slash fuel weights of over 20 tons per acre (Fahnestock, 1968).

This forest situation is considered as Fuel Type B for the National Fire Danger Rating System.

E. Clear-cut slash

Clear cutting is not the usual method of harvesting ponderosa pine, but occasionally it is done. Areas where bark beetles have killed most of the trees, where land clearing is being done, or where a stand is being regenerated are examples where clear cutting is used.

The fuels consist of heavy concentrations of needles, limbs, tops, and some unmerchantable boles. The slash is generally continuous and can reach depths of 3 or 4 feet. The grass, forbs, and shrubs that were on the forest floor also contribute to the fuel loading.

Fuel Type I is suggested for this even though the type descriptions say to use type D.

F. Meadow Invasion

Due to the absence of extensive wildfire because of good fire prevention, grassland openings are slowly being invaded by ponderosa pine. Unchecked, this important forage will gradually be converted to a dense pine stand. Burning is considered here as a forest management practice to maintain the meadows for livestock feed and to enhance the beauty of the Black Hills area by having these scenic meadows kept intact. The fuel consists mostly of grass and should be cured at the time of burning and be in amounts of at least 3 tons per acre (U.S. Forest Service, 1973).

Fuel Type A is considered appropriate for use here.

V. Fire as a Tool of Management

Fire has long been used as a silvicultural tool in the ponderosa pine stands of Oregon, Washington, California, and to a limited extent in other states as well as in some provinces of Canada. Success with this use of fire is evident by the many many articles written on the subject. Most notable are H. H. Biswell and Harold Weaver who have pioneered and practiced most of the ponderosa pine burning in this country.

In the past, most forest managers have been reluctant to utilize fire as a management tool, but that attitude appears to be rapidly changing. Controlled burning in the foothill region of the Black Hills has been successfully demonstrated as a useful practice for maintaining high quality grasslands and reducing potentially dangerous ground fuel accumulations (Gartner, 1972).

Research has shown that controlled burning is possible during spring, fall, and winter and that it appears to be a useful tool for maintaining bluestem grass ranges. Controlled burning is advisable before thinning or logging to reduce seedling numbers and ground fuel accumulations. Slash burning is also done to remove the fire hazard and eliminate the host trees for bark beetles.

Natural fire can be successfully replaced by periodic prescribed fires, and these fires can do the following silvicultural jobs: --

1. reduce the fire hazard and maintain it at an acceptable level.
2. improve forage and browse production.
3. assure the dominance of pine over other thin barked species.
4. release soil nutrients that otherwise might not be available to trees.

A discussion of the specific use of fire in each of the six recognized fuel types follows.

A. Fire use in overstocked stands

The effort here is to use fire as a thinning agent. The fire intensity is defined by fuel condition and weather at the time of burning and controlled more precisely by igniting techniques. The small trees 1 to 3 inches in diameter can be killed by cambium heating; while the larger ones survive because of their thicker bark. Igniting by strips using strip head fires is a workable technique.

The fire prescription for this fuel type takes into consideration the need for extreme control of flame height and the length of fire pulse time so that no crowning occurs and that heat around the tree bases is controlled. This practice can be used where fire has been absent for 20 or 30 years; however, the risk of attracting bark beetles is high.

B. Fire use in open grown stands

The use of fire here is for the maintenance of acceptable fuel hazard levels. Some small trees will be killed by the fire, but the objective of this kind of burning is not for thinning, but rather for fuel reduction of needle and twig accumulation. Some increase in grass production and shrub growth is anticipated.

This burning can be done under a wider range of conditions than used for overstocked stands because the trees are more widely spaced and their bark is thicker. The fire can be more intense if need be because the thicker bark trees can stand more basal heat.

Igniting can be done more rapidly than by using the narrow strip head fires needed in the overstocked stands. Igniting long lines with wider spaces between lines is possible because the fire can reach its steady state of fuel consumption and not be too intense.

C. Fire use in selectively cut stands

Fire is used here to remove the additional slash hazard caused by selective cutting. Some fuel preparation work is generally done, either just moving fuel concentrations away from "leave trees" and then burning the slash in a broadcast fashion, or piling all the slash and burning the piles when the fire won't spread out of the piles. Both practices have merit, the latter is more costly, but it allows the burning to be done later in the season (even in winter if piles are partially covered with plastic or treated paper).

D. Fire use in thinning slash

(Sackett and Wade, 1970) had some success burning thinning slash at night. I feel it is risky and difficult even at night because of the heavy fuel loading, the close proximity of the fuels to the trees, and the relatively thin bark of the leave trees.

Burning might be done in the spring of the year after the thinning was done when only the fine fuels were dry enough to burn. Pine slash keeps the needles on several years. This would reduce the flash fire hazard some, but would not eliminate the hazard entirely. Narrow igniting strips would be necessary and very careful control of fire intensity would be mandatory.

E. Fire use in clear-cut areas

The fire's job here is to consume all the woody material and most of the forest duff so that a new stand can be started either by planting or by natural seeding. A hot, quick fire is needed that burns with central tendency so as to protect the surrounding area from heat radiation.

Igniting can be done with torches or by pre-set electrical ignitors so that the area burns quickly and that smoke and embers go straight up. A convection column is created by this fire of relatively high intensity.

F. Fire use to perpetuate meadows

When it is desirable to maintain grass that is being invaded by ponderosa pine seedlings, fire can be used to burn both grass and seedlings. The grass will come back because the fire does not kill the roots; whereas the seedlings will be killed by the fire and are unable to resprout.

If adequate boundary protection measures are taken, this burning can be done under fairly severe burning conditions. The igniting should be done so as to widen the protective boundaries first, and then allow the fire to make runs across the entire area with the wind. Large areas can be burned in this manner with only a few men.

VI. Prescribed Weather

A. General weather parameters

1. Synoptic situation

The general effect of pressure systems is that of changing wind direction, wind velocity, air mass temperatue-moisture characteristics, and changes in stability. In the Black Hills, there are 5 frontal systems per month, average from April through November. These systems cause significant changes in most atmospheric parameters and should be avoided for prescribed buring operations.

The unsettled weather associated with these systems lasts about 36 hours, which leaves 22 days a month without severe disturbances from frontal weather. Allowing for variation of longer lasting disturbances, there should be at least 16 days per month free from this kind of disturbance. If the burning is done under the influence of High pressure, days can be picked that fit the more localized prescribed items such as temperature, relative humidity, and ground wind, and there should be plenty of chances to do prescribed burning.

2. Temperature

Temperature can be a limiting factor at the high end more than at the low. Temperatures in excess of 90°F. should be avoided because pine needles produce terpenes and other volatiles as the temperature rises. These volatiles often aid in crown fires and burning should not be attempted when there is a threat of crown fire. Also, temperature above 90°F. affects relative humidity greatly, and even an air mass that has a moderate amount of absolute humidity, will become relatively much drier as the temperature goes up. The minimum temperature can be as low as 50°F. and satisfactory burns can be accomplished if fuel and other factors are favorable.

3. Relative humidity

Atmospheric moisture affects the fuel moisture inversely by fuel size class. Since the ponderosa pine and grass types are made up of short time-lag fuels, relative humidity is very important. The range of humidity suitable for burning in this type is from 10% to 50% depending on percent of fine fuels present.

4. Wind at the fire site

Steady wind even though it be of velocity as high as 15 m.p.h. is tolerable for prescribed burning in the pine type. Gusts are always tricky and if possible days when gusty winds are present should be avoided. Sometimes very unstable air will produce gusty winds, and though unstable air is great for smoke dispersal, it may be a disadvantage if gustiness results. In steep topography, burning can be done with as little as 2 m.p.h. of wind.

5. Nighttime recovery

A hygrothermograph equipped with the windiness pen should be used for all prescribed burning (Fischer, 1969). The 24-hour traces of temperature and relative humidity show the temperature and relative humidity recovery during the night as well as the time of wind cease. It is desirable to have a relative humidity recovery of at least 20% at night and have the winds decrease by 2000 hours.

B. Fuel moisture

Fuel moisture is a very important feature of fuel condition in the practice of prescribed burning. It is not easy to measure now, but instrumentation is being developed to measure it electronically (McLeod, 1974). Fuel moisture can be measured directly by drying and weighing actual fuel samples, which is not practical for operational burning.

Fuel moisture can be approximated closely by either weighing ½" wooden dowels called fuel moisture sticks or by using the Fine Fuel Moisture Percent as described for the National Fire Danger Rating System (Deeming, 1972). The latter is preferable to use until the electronic moisture meter can be purchased commercially.

VII. Prescriptions

A. General conditions common to all fuel types

1. Time of year ....April through December

2. Synoptic situation ....High pressure influence
   ....No fronts predicted
   ....500 mb. wind less than 60 knots
   ....lapse rate stable or neutral

3. Relative humidity recovery...At least 20%

4. Gradient wind 1/ ....Any direction

B. Specific conditions for each fuel type

1. Overstocked stands (fuel type [illegible] C εou/E

   a. fuel moisture ....15% to 25%
   b. time of day ....1500 hrs to 1800 hrs.
   c. local situation
      temperature ....70° to 80°
      relative humidity.....20% to 30%
      wind velocity ....3 mph to 8 mph
   d. burning index ....less than 25

2. Open grown stands (fuel type C)

   a. fuel moisture ....10% to 30%
   b. time of day ....1200 hrs. to 2000 hrs.
   c. local situation
      temperature ....65° to 85°
      relative humidity.....15% to 50%
      wind velocity ....5 mph to 10 mph
   d. burning index ....less than 30

1/ population centers are not a significant factor in the Black Hills, so smoke dispersal, if fairly adequate at the fire site, should suffice.

3. Selectively cut stands (slash piled) (fuel type B)

   a. fuel moisture ....10% to 30%
   b. time of day ....1000 hrs. to 1800 hrs.
   c. local situation
      temperature ....65° to 85°
      relative humidity.....15% to 50%
      wind velocity ....5 mph to 8 mph
   d. burning index ....less than 60

4. Thinning slash (fuel type B)

   a. fuel moisture ....20% to 30%
   b. time of day ....2000 hrs. to 2400 hrs.
   c. local situation
      temperature ....60° to 70°
      relative humidity.....30% to 50%
      wind velocity ....3 mph to 8 mph
   d. burning index ....less than 50

5. Clear cut slash (fuel type I)

   a. fuel moisture ....10% to 25%
   b. time of day ....1400 to 2400 1/
   c. local situation
      temperature ....60° to 85°
      relative humidity.....15% to 50%
      wind velocity ....0 to 6 mph
   d. burning index ....less than 50

6. Meadows (fuel type A)

   a. fuel moisture ....less than 12%
   b. time of day ....1200 hrs. to 1600 hrs.
   c. local situation
      temperature ....70° to 90°
      relative humidity.....10% to 25%
      wind velocity ....5 mph to 12 mph
   d. burning index ....less than 12

.........I feel this prescription is on the "tight side", and that with experience, wider ranges can probably be used for most parameters........

1/ avoid igniting at the wind transition period from about 1700 hrs. to 1900 hrs.

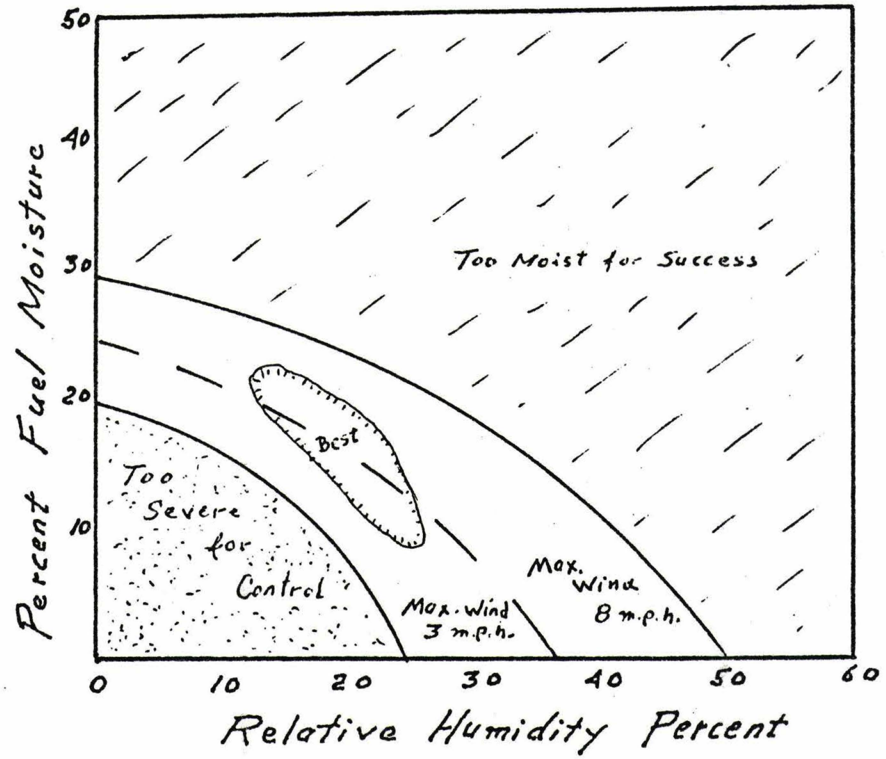
The following charts may be helpful in selecting conditions for prescribed burning in the various fuel types.

The idea for the charts came from.-

SWIFCO. 1968. Guide to prescribed fire in the southwest. Southwest Interagency Fire Council, University of Arizona.

I used Black Hills prescriptions in the Prescribed Fire Charts.

Prescription Chart

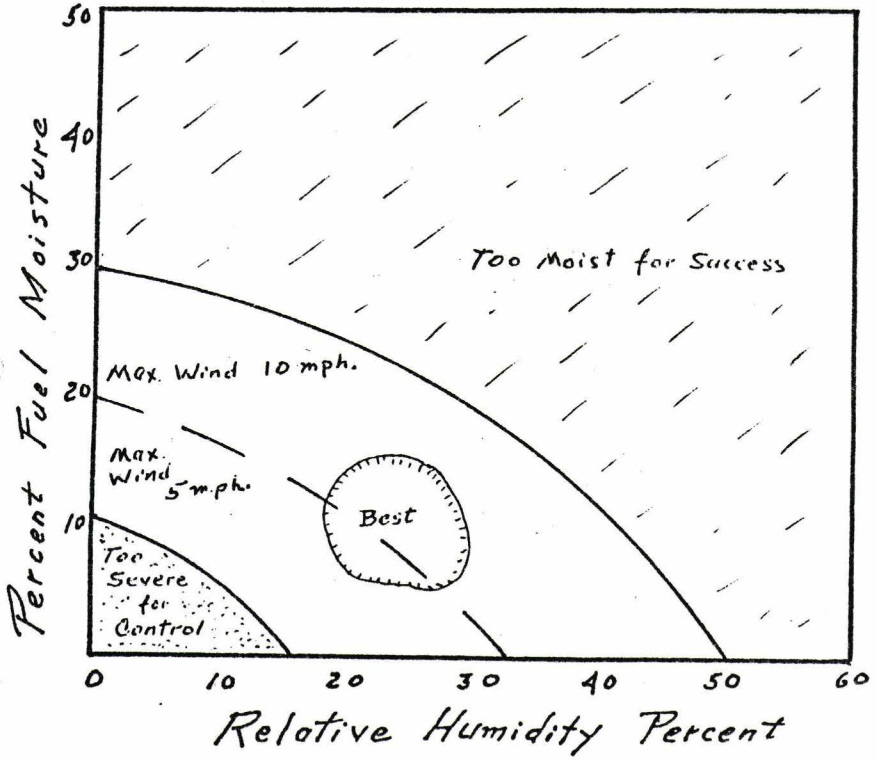


Fuel Types

Thinning Slash . Fuel Type B

Overstocked Stands, Fuel Type C

Prescription Chart

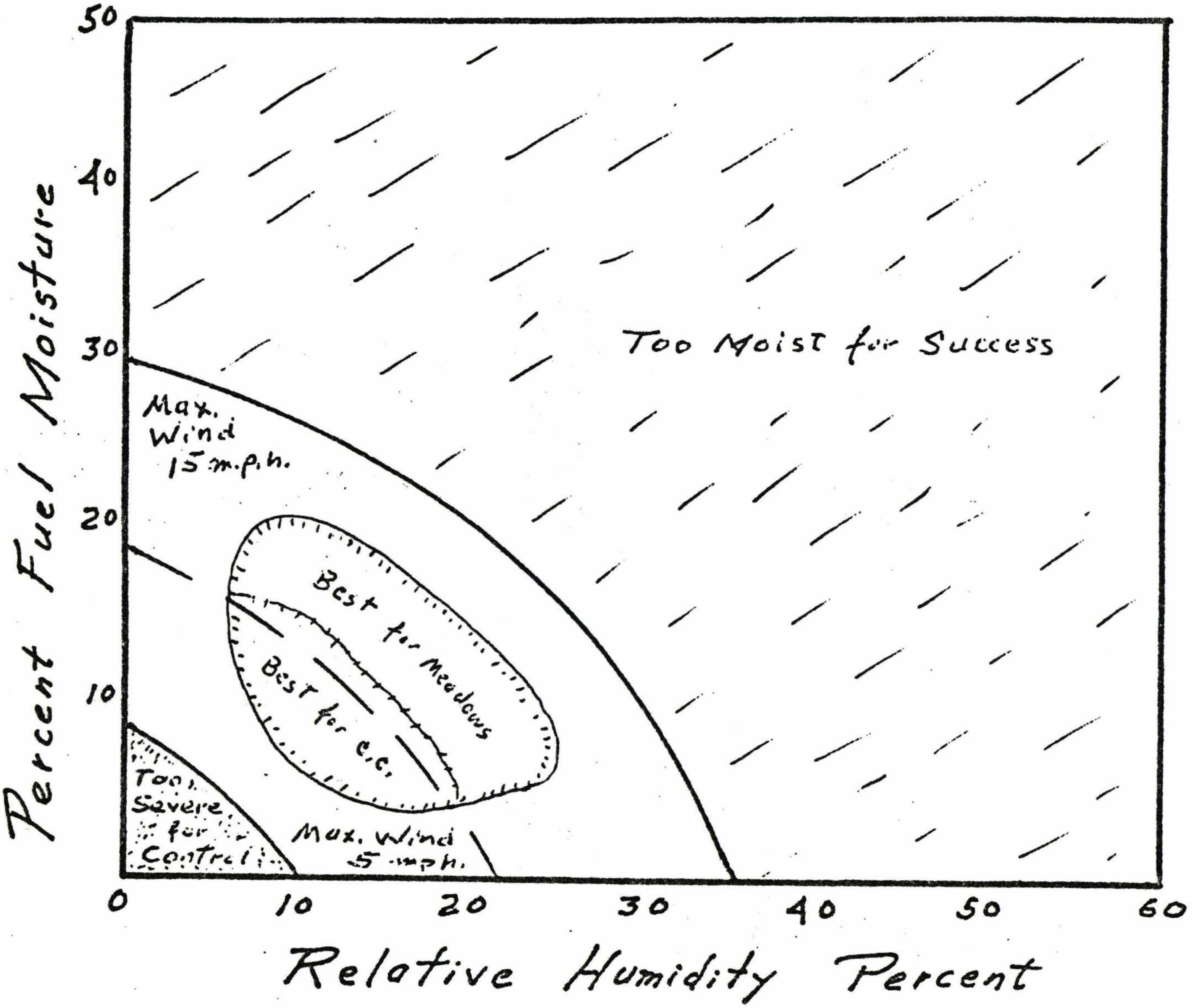


Fuel Types

Open grown stands, Fuel Type C

Selectively cut stands, Fuel Type B

Prescription Chart



Fuel Types

Meadows, Fuel Type A

Clear cut slash, Fuel Type I

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